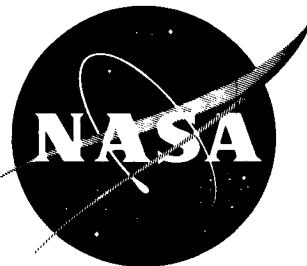


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# ALKALI METALS BOILING AND CONDENSING INVESTIGATIONS

## Quarterly Progress Report 7

Edited by  
**FRANK E. TIPPETS**

prepared for  
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**SPACE POWER AND PROPULSION SECTION  
MISSILE AND SPACE DIVISION**

**GENERAL ELECTRIC**

**CINCINNATI 15, OHIO**

ALKALI METALS BOILING AND CONDENSING INVESTIGATIONS

QUARTERLY PROGRESS REPORT 7

Covering the Period  
January 1, 1964 through March 31, 1964

Frank E. Tippets, Manager  
Heat Transfer Project \*

prepared for

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Technical Management  
NASA - Lewis Research Center  
Nuclear Power Technology Branch  
Ruth N. Weltmann

SPACE POWER AND PROPULSION SECTION  
MISSILE AND SPACE DIVISION  
GENERAL ELECTRIC COMPANY  
CINCINNATI, OHIO 45215

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FOREWORD

Principal technical contribution to the program, within General Electric Company, during the Quarter was by the following individuals.

300 KW Loop Project Engineer	J.R. Peterson
100 KW Loop Project Engineer	J.A. Bond
50 KW Loop Project Engineer	S.G. Sawochka
Pool Boiling Heat Transfer Investigation	C.F. Bonilla
Multi-Tube Boiler Design	R.R. Oliver D.R. Ferguson R.S. Stankiewicz
Facilities	J.A. Amos R.A. Fuller
Instrumentation	W.H. Bennethum
Materials Support	W.R. Young
Special Analysis	G.L. Converse
Report Preparation	G.L. Converse

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## NOMENCLATURE

### Latin Letter Symbols

<u>Symbol</u>	<u>Quantity</u>	<u>Unit</u>
A	Area	ft <sup>2</sup>
C	Specific heat	Btu/lb <sub>m</sub> °F
D	Diameter	ft
F	Function	°F
f	Friction factor	Dimensionless
G	Mass velocity (total flow rate per total flow area)	lb <sub>m</sub> /sec ft <sup>2</sup>
g	Acceleration due to gravity	ft/sec <sup>2</sup>
g <sub>o</sub>	Conversion factor	32.174 ft-lb <sub>m</sub> /lb <sub>f</sub> sec <sup>2</sup>
H	Specific enthalpy	Btu/lb <sub>m</sub>
H <sub>fg</sub>	Latent heat of vaporization	Btu/lb <sub>m</sub>
h	Heat transfer coefficient	Btu/hr-ft <sup>2</sup> °F
J	Conversion factor	777.97 ft-lb <sub>f</sub> /Btu
k	Thermal conductivity	Btu/hr-ft °F
L	Length	ft
L'	Length of test section in bulk boiling	ft
N <sub>Nu</sub>	Nusselt number (hD/k)	Dimensionless
N <sub>Pe</sub>	Peclet number (DV <sup>ρ</sup> C <sub>p</sub> /k)	Dimensionless
N <sub>Pr</sub>	Prandtl number (μC <sub>p</sub> /k)	Dimensionless
N <sub>Re</sub>	Reynolds number (ρ VD/μ)	Dimensionless
N <sub>t</sub>	Number of tubes	Dimensionless

NOMENCLATURE (Continued)

<u>Symbol</u>	<u>Quantity</u>	<u>Unit</u>
P	Pressure	$\text{lb}_f/\text{ft}^2$
Q	Quantity of heat	Btu
q	Rate of heat transfer	Btu/sec
R	Thermal resistance	$\text{ft}\cdot\text{sec}^{\circ}\text{F}/\text{Btu}$
S	Area of insulation	$\text{ft}^2$
T	Temperature	$^{\circ}\text{F}$
U	Overall heat transfer coefficient	$\text{Btu}/\text{hr}\cdot\text{ft}^2\text{ }^{\circ}\text{F}$
V	Velocity	$\text{ft/sec}$
W	Weight flow rate	$\text{lb}_f/\text{sec}$
X	Thickness of insulation	ft
x	Flowing quality	$\frac{\text{lb}_m \text{ per sec of vapor}}{\text{lb}_m \text{ per sec of fluid}}$
Z	Refers to location along the boiler length	ft

Greek Letter Symbols

$\alpha_1, \beta_1, \gamma_1$

Constants related to the dimension of the annulus as follows;

Dimensionless

$$\alpha_1 = 4.63 + 0.686 (D_o/D_i)$$

$$\beta_1 = 0.02154 - 0.000043 (D_o/D_i)$$

$$\gamma_1 = 0.752 + 0.01657 (D_o/D_i) - 0.000883 (D_o/D_i)^2$$

$\lambda$

Thermal diffusivity ( $k/\rho C_p$ )  $\text{ft}^2/\text{hr}$

$\beta$

Orifice coefficients

$$\beta = \frac{D_{\text{orifice}}}{D_{\text{tube}}}$$

Dimensionless

NOMENCLATURE (Continued)

<u>Symbol</u>	<u>Quantity</u>	<u>Unit</u>
$\Delta$	Finite difference	Dimensionless
$\epsilon$	Radiation emissivity	Dimensionless
$\mu$	Dynamic viscosity	$\text{lb}_m/\text{hr}\cdot\text{ft}$
$\nu$	Kinematic viscosity or momentum diffusivity	$\text{ft}^2/\text{hr}$
$\rho$	Mass density	$\text{lb}_m/\text{ft}^3$
$\sigma$	Stefan-Boltzmann Constant	$\text{Btu}/\text{hr}\cdot\text{ft}^2 \text{ }^\circ\text{F}^4$
$\psi$	Ratio of eddy diffusivity of heat to eddy diffusivity of momentum	Dimensionless
$\phi$	Integrated average Martinelli multiplier	Dimensionless

Subscripts

<u>Symbol</u>	<u>Quantity</u>
av or avg	Average
b	Bulk fluid, bottom
bott	Bottom
c	Calculated
elect	Electrical
g	Vapor phase
i	Inside
in	Inlet
K	Potassium

NOMENCLATURE (Continued)

<u>Symbol</u>	<u>Quantity</u>
L, l	Liquid phase
m	Measured
Na	Sodium
o	Outside
out	Outlet
P	at constant pressure
t	Tube
Top	Top
TPF	Two-Phase Friction
v	Refers to the volumetric hydraulic diameter
w	Water
w	Value at the wall
—	If a quantity is already subscripted, a bar over the quantity indicates an average value
^	Weighted average

## I. SUMMARY AND FORECAST

### SUMMARY

This program is being conducted for the National Aeronautics and Space Administration under Contract NAS 3-2528 to obtain two-phase heat transfer and fluid flow data for sodium and potassium under conditions of boiling and condensing. Test equipment development, materials studies and theoretical analysis related to the experimental work are conducted as a support effort. The current work includes the design and development of a multi-tube, once-through boiler. The following items summarize the work performed during the quarter ending March 31, 1964.

### 300 KW Loop Project

No boiling runs were obtained with the 300 KW loop this quarter, due to required repairs resulting from failure of the test section bellows and time required for subsequent flushing runs. Therefore, the loop operating time above 800° F remains at 2200 hours. The loop is presently shut down for un-plugging operations which are in progress. Depending on the cause of the plugging, which is in the process of being determined, it is possible that experimental operation can be resumed in April. However, if dismantling of the loop is required, a shutdown period of perhaps several weeks may be necessary.

Design of the multi-tube boiler to be fabricated for testing in the 300 KW loop is nearing completion. Preliminary design for an associated superheater unit has been initiated.

Boiling heat transfer data obtained in the 300 KW facility during the period December 26 - 31, 1963 are tabulated herein.

100 KW Loop Project

Following completion of instrumentation changes made on the 100 KW loop during January, the facility was put into boiling operation the first part of February and has been operating steadily, on a routine basis throughout the remainder of the quarter.

A total of 97 stable boiling heat transfer data points were taken during this quarter, all of which have been reduced and are tabulated herein. The total operating time above 800°F of this loop is 3381 hours.

Design of the 100 KW loop modification, to enlarge the range of data that can be obtained is nearly complete, pending design review by the General Electric Company and subsequent approval by NASA.

50 KW Loop Project

Except for a brief interval of operation during the first week in March, the facility has been shut down for repairs throughout the quarter, due to test section failure last December and subsequent failure of the potassium loop MSA pump. The defective pump has been replaced by an available used pump and a new one is on order. The repaired original test section has been re-installed. Unfortunately, some of the thermocouples in this

test section are now inoperative; hence, usage of the test section is questionable. A replacement test section should be available in April.

Reduction of all the liquid-liquid heat transfer data obtained in the facility was completed this quarter. Initial reduction of the condensing data was completed during this quarter and the results are presented in Reference 3.

As soon as the loop has been brought into operation, testing will resume at 1150 - 1250<sup>o</sup>F and intermediate power levels, followed by testing at powers up to 50 KW. A brief test plan is presented herein.

#### Pool Boiling Investigation

The effort during the quarter was directed primarily toward determination of the overall heat losses for the pool boiler, as described in detail in Section V.

#### Facilities, Materials and Instrumentation

Detailed accountings of the work conducted throughout the quarter in support of the three facilities are presented in Sections VI, VII and VIII.

#### FORECAST

The current contract period terminates July 31, 1964. Increased emphasis throughout the new quarter will be placed on analyzing and

correlating the several blocks of experimental data that have been obtained. Work to be proposed for contract continuation will be scoped.

#### 300 KW Loop

The 300 KW loop is currently shut down while efforts are underway to determine the cause and appropriate remedial action for plugging on the primary sodium side. Depending on the action to be taken, it is not anticipated that experimental operation will resume before the end of April, 1964. If major disassembly of the loop is required, the shut-down period could require several additional weeks. A course of action will be decided within the next few days. If operation can be resumed soon after the first of May, then it appears that planned testing with the one-inch tube using helical inserts of 2-inch and 6-inch pitch, respectively, could be completed by the end of the current contract period. Potentially, planned testing with the wand insert could also be completed before the end of the contract period.

#### Multi-Tube Boiler

Design of the multi-tube boiler is nearly complete, pending design review by the General Electric Company and subsequent approval by NASA.

#### 100 KW Loop

Design of the 100 KW loop modification is ready for submission to the design review board. Approval by NASA will depend upon the recommendation of the design review board. Experimental operation of the loop with the presently installed 3/4-inch smooth tube test section will continue according

to test plan until completion of planned runs. At this time, anticipated to be in early May, the loop will be shut down so that work on the modification can proceed. It is planned that experimental boiling operation will be resumed in June, following the modification. Current plans are to start operation then with the 3/4-inch smooth tube test section followed by testing with inserts.

#### 50 KW Loop

It is expected that planned condensing experiments with the 50 KW loop, using the smooth 5/8-inch I.D. test section will resume the week beginning April 20. However, two of the five thermocouple slots at each of the two axial locations in the presently installed test section are defective, leaving a total of three thermocouples at each location for determination of the radial temperature profile. Hence, it may prove more desirable, depending on the appearance of the data obtained, to replace this test section as soon as the replacement section becomes available. Preparation of the replacement test section is nearing completion and is expected to be available before the end of April. Current plans are to complete tests with the smooth 5/8-inch I.D. test section first, and to then follow with planned tests using the same tube with a twisted ribbon having a twist ratio of six\*,

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\* The twist ratio is the ratio of the length required for a  $360^{\circ}$  turn divided by the tube diameter.

## II. 300 KW PROJECT

### Status of Loop and Test Section

No boiling runs were obtained during this reporting period with the 300 KW loop. The months of January and February were spent in repairs necessitated by the bellows and insert failures which occurred in the latter part of December. Flushing runs, necessitated by the sodium and potassium mixing caused by the failure, were initiated in March. Plugging encountered in both sodium and potassium loops required additional clean up time, which was carried on through the end of the reporting period. The potassium loop was successfully unplugged; and work is continuing for the sodium side.

Several changes were made in the loop and test section during this reporting period. These are;

1. The thermal shields formerly required for protection of the molybdenum to L-605 bimetallic joint were removed from the boiler tube, since they are not required for the presently installed L-605 tube. These shields were undesirable from a heat transfer standpoint in that they were only partially effective in blocking heat transfer and thus created uncertainty in the active boiler heat transfer length. Removal of the shields increased the active boiler tube length from 67.5-inches to 84.4-inches.
2. The maximum air flow rate to the horizontal and vertical condensers was increased by removal of the air heater and modification of the air supply lines, thereby reducing flow resistance. The orifices monitoring the air flow rate to the horizontal condenser were removed from

the loop, calibrated and reinstalled.

3. The 2-inch pitch helical insert was modified to provide additional support for the  $\frac{1}{4}$ -inch O.D. center body tube at the boiling potassium tube exit. This was accomplished by replacing the  $\frac{1}{2}$ -inch O.D. tube of 0.049-inch wall thickness which supported the  $\frac{1}{4}$ -inch O.D. center body with a 1.125-inch O.D. tube of 0.187-inch wall thickness. This tube was welded into the top cap of the boiler. Additional support was obtained by extending the helical ribbon in length so that it covered the entire length of the center body tube and provided restraint to lateral movement. The modified insert also included 7 sheathed thermocouples with junctions spaced along the active heat transfer length.
4. The flange at the top of the test boiler to which the boiler support hanger is attached was wrapped with heating wire and heavily insulated to minimize heat losses from this region. A thermocouple was installed to monitor the flange temperature. Examination of previous data had shown that heat losses from this area introduce significant error in liquid-liquid runs at low potassium flow rates.
5. The number of thermocouple rings on the boiler shell was increased from seven to eleven. This modification will increase the accuracy in locating the various regimes of heat transfer in boiling runs.

The potential operating capability of the presently installed boiler tube has been changed by the removal of the thermal shields and by the addition

of the helical insert. In addition, the air flow rate to the condensers was increased as described in 2 above. The following new factors were considered in the calculational procedure used to determine the potential operating capability of the 300 KW facility after these modifications.

1. The boiler tube heat transfer area was increased due to the removal of the thermal shields.
2. The mass flow rate at which choking occurs was reduced in proportion to the increase in potassium velocity caused by the insert.
3. The change in potassium temperature across the boiler (formerly assumed zero because of negligible pressure drop) was calculated from the potassium pressure drop. This was necessitated by the increase in the pressure drop with the insert over that for the no-insert case.
4. The condensing capability of the facility was recalculated to account for the increased condenser air flow rate (see Item 2, Page 7).

The operating characteristics of the 300 KW as reported in Reference 9 are shown in Figure 1. The results of the new calculations are shown in Figure 2. It is emphasized that this figure shows the maximum operating capabilities since the potassium heat transfer resistance has been assumed negligible. It is expected that the boiler tube with insert will approach more closely the calculated limitations than the tube without insert, since the region of film boiling, where the potassium thermal resistance is large, is expected to be reduced by the insert.

The results of the new calculation also show that the condenser limiting line is displaced vertically upward from its position on Figure 1 and off of Figure 2. The maximum condensing capability for the horizontal condenser alone is 410 KW at 1200°F and 595 KW at 1600°F. The facility as modified is not limited by the condensing capability.

#### Tube Bundle Boiler Design

##### Thermal and Hydraulic Design

Introduction. The design of a tube bundle boiler for the 300 KW test facility was initiated during the fourth quarter of 1963. The following boiler performance criteria were specified:

1. The minimum allowable design exit potassium temperature is 1600°F.
2. The exit quality must be 98 to 100 per cent.
3. The minimum number of tubes is three.
4. Provisions will be made for a superheater to supply 50°F superheat. The boiler superheater combination shall effectively utilize the present power capability of the 300 KW test facility.

A coiled tube bundle was selected as the final design, and preliminary hand calculations were carried out, to rapidly estimate the tube length and size requirements. The essentials of the selected design were:

Number of tubes	3
Tube I.D.	0.674 in.
Tube O.D.	0.75 in.
Tube Length	18 to 22 ft.
Effective heat transfer area	9.46 to 11.57 ft <sup>2</sup>
Design power level	200 to 240 KW
T <sub>Na</sub> , in.	1850°F
T <sub>K</sub> , in	1700°F
T <sub>K</sub> , out	1650°F
w <sub>Na</sub>	14 lb <sub>m</sub> /sec (max.)
w <sub>K</sub>	0.23 to 0.28 lb <sub>m</sub> /sec
G <sub>K</sub>	30 to 37 lb <sub>m</sub> /ft <sup>2</sup> -sec
U (X, 0.0 to 0.7)	3000 Btu/ft <sup>2</sup> hr-°F
U (X, 0.7 to 1.0)	200 Btu/ft <sup>2</sup> hr-°F

Concurrent with the hand calculations, a generalized IBM FORTRAN Program was developed to provide a rapid method of boiler design and an estimate of design point performance. Results are presented for the proposed coiled tube boiler design point. Also included are:

1. Shell side pressure drop analysis.
2. Inlet orifice requirements.

Design Procedure for the Boiler. The determination of the required length of boiler tube for fixed tube geometry and primary and secondary conditions involves a simultaneous solution of the heat transfer and pressure drop equations. In the ensuing analysis, heat losses are neglected.

Heat Transfer. The expression for differential heat transfer rate may be written in terms of quality as:

$$\frac{dL}{dx} = \frac{\pi D_i H_f g G_K}{4 U_i (T_{Na} - T_K)} \quad (1)$$

where  $U_i$  = overall heat transfer coefficient for the length  $dL$

For a counterflow boiler, the sodium temperature distribution may be represented as a function of quality by:

$$T_{Na} = T_{Na,in} - \frac{(x_{out} - x) \pi D_i G_K N_t H_f g}{4 W_{Na} C_{p,Na}} \quad (2)$$

For conservative length calculations, the potassium temperature may be assumed constant and equal to the inlet saturation temperature. This assumption yields the lowest thermal driving force, and hence, the most conservative estimate of surface area requirements. If it is postulated that the overall heat transfer coefficient is essentially constant over a given quality interval, Equation (1) may be integrated, after substitution for the sodium temperature distribution. The result for a quality interval  $x_1$  to  $x_2$  is then:

$$L_{\Delta x} = \frac{(W C_p)_{Na}}{\pi D_i N_t U_i} \ln \left[ \frac{4(W C_p)_{Na}(T_{Na,in} - T_{K,in}) - \pi D_i^2 G_K N_t H_f g (x_{out} - x_2)}{4(W C_p)_{Na}(T_{Na,in} - T_{K,in}) - \pi D_i^2 G_K N_t H_f g (x_{out} - x_1)} \right] \quad (3)$$

The total length of the boiler may then be expressed in terms of the inlet saturation temperature as:

$$L_{(x_{in} \text{ to } x_{out})} = \frac{(N_t)_{Na}}{\pi D_t N_t} \int_{x=x_{in}}^{x=x_{out}} \frac{1}{U_i} \ln \left[ \frac{4(WCP)_{Na}(T_{ain}-T_{kin}) - \pi D_t^2 G_K N_t H_{fg}(x_{out}-x_2)}{4(WCP)_{Na}(T_{ain}-T_{kin}) - \pi D_t^2 G_K N_t H_{fg}(x_{out}-x_1)} \right] \quad (4)$$

Pressure Drop. The boiler length may also be expressed in terms of the inlet saturation temperature by means of the pressure drop relationship. The total pressure drop is composed of the friction pressure drop and the momentum pressure drop. Two options are available for estimating the two-phase friction pressure drop:

1. The pressure drop may be computed assuming the flow of 100% vapor.
2. The pressure drop may be computed using an "integrated average" Martinelli multiplier on the all liquid pressure drop.

The former method is expected to give a more conservative answer in cases in which the quality goes from 0 to 1.0. The momentum pressure drop is based on the so-called "homogeneous model", where the ratio between liquid and vapor phase velocities is 1. This assumption yields a maximum value for the momentum pressure drop. The defining equations then are:

#### Gas Phase $\Delta P$ Friction

$$L_{\Delta P} = \frac{\bar{P}_g g_o D_t}{2f G_K^2} \left\{ (P_{kin} - P_{kout}) - \frac{G_K^2}{g_o P_L} \left[ (1-x_{out}) + x_{out} \left( \frac{P_L}{P_g} \right) - 1 \right] \right\} \quad (5)$$

#### Two Phase $\Delta P$ Friction

$$L_{\Delta P} = \frac{\bar{P}_L g_o D_t}{2f G_K^2 \phi} \left\{ (P_{kin} - P_{kout}) - \frac{G_K^2}{g_o P_L} \left[ (1-x_{out}) + x_{out} \left( \frac{P_L}{P_g} \right) - 1 \right] \right\} \quad (6)$$

where  $\phi$  = Integrated average Martinelli Multiplier

$$\phi = \frac{1}{(x_{out} - x_{in})} \int_{x_{in}}^{x_{out}} \frac{\left(\frac{dp}{dx}\right)_{TPE}}{\left(\frac{dp}{dx}\right)_L} dx \quad ; \quad p_{kin} = p_{kin}(T_{kin})$$

The required tube length and inlet saturation temperature may now be determined by simultaneous solution of Equations (4) and (5) or Equations (4) and (6), depending on the option chosen for computing the friction pressure drop. As indicated by the equations, the calculation is necessarily of an "iterative" nature; viz, inlet saturation temperatures are assumed until the lengths computed by the heat transfer and the pressure drop equations are equal.

Description of IBM Boiler Design Point Program. A FORTRAN Program was written to provide a rapid method for solving Equations 1 through 6 of the preceding section. The requisite input to the program consists primarily of the boiler power level, tube geometry, sodium flow rate and inlet temperature, and desired exit quality. Potassium heat transfer coefficients must be specified as a function of quality. Sodium heat transfer coefficients may be either input as a function of quality or calculated for an annulus using Dwyer's relationship (Reference 1).

$$N_{Nu} = \alpha_1 + \beta_1 (\bar{V} N_{Pe})^{\gamma_1}$$

where  $\alpha_1$ ,  $\beta_1$  and  $\gamma_1$  are functions of annulus height.

In the program, maximum and minimum values of inlet saturation temperature are picked such that the answer is spanned quickly. A subroutine then iterates until the difference between the lengths computed by the heat

transfer and the pressure drop equations are within a specified percentage tolerance of one another. Following the determination of the required length, heat flux distributions are calculated based upon the inlet saturation temperature and the exit saturation temperature. This latter procedure serves to bracket the heat flux distribution between maximum and minimum values. The additional output from the program consists of the tube side pressure and temperature drop, and quality, heat transfer coefficients, and heat fluxes as a function of length.

The program was utilized to check the design point of the proposed multi-tube boiler. The essential results are shown in Figure 3 as a plot of boiling tube length as a function of boiler power level in the region from 200 to 240 KW. It should be noted that different heat transfer coefficients were utilized in the hand and machine calculations. In the case of the hand calculations, an overall heat transfer coefficient of  $3000 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  was assumed from 0 to 70 per cent quality and an overall heat transfer coefficient of  $200 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  was assumed from 70 to 100 per cent quality. In the case of machine calculations, a sodium heat transfer coefficient of  $5000 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  was assumed. The potassium heat transfer coefficients were assumed to be  $5000 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  in the region from 0 to 70 per cent quality and  $200 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  in the region from 70 to 100 per cent quality. The use of these coefficients yielded overall coefficients of  $1725 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  and  $186 \text{ Btu}/\text{ft}^2 \text{hr}^{-1} \text{F}^0$  for the 0 to 70 per cent and 70 to 100 per cent quality regions, respectively. The former coefficient is conformal with overall coefficients obtained in 300 KW straight tube tests. The agreement between the hand and the machine calculated results is considered good in spite of the difference in heat transfer

coefficients. The actual length of the coiled tube bundle is also shown in Figure 3. It is seen that this length lies between the IBM length values calculated by the program at a nominal power level of 240 KW. The IBM print-outs applicable to Figure 3 are listed in Tables 2 and 3. The nomenclature for the printout is given in Table 1. The approximate running time per case was four seconds, with iteration to an accuracy of  $\pm$  0.5 per cent in length.

Shell-Side Pressure Drop. The shell side sodium pressure drop for the coiled tube geometry was estimated using a modified form of the Gunter-Shaw relationship for cross-flow in a bare tube heat exchanger (Reference 2). The coil tube was approximated as a hypothetical tube bank in cross flow. The Reynolds number was based on the velocity in the minimum cross-sectional area, with the characteristic length being taken as the volumetric hydraulic diameter. This latter quantity is defined as four times the net free volume of the shell side divided by the friction surface area. The friction factor relationship was obtained from Reference 2, and is given by the following equation:

$$f = 1.92 (N_{ReV})^{-0.145}$$

where  $N_{ReV}$  is based on the volumetric hydraulic diameter.

The estimated cross-flow pressure drop for the proposed coil design is shown as a function of sodium flow rate in Figure 4. For the design sodium flow rate of  $14 \text{ lb}_m/\text{sec}$ , the estimated pressure drop is 1.8 psi. Contraction and expansion losses in the headers are estimated to be 1.2 psi, assuming the loss of a full velocity head for each contraction and expansion.

A  $\frac{1}{4}$  scale model of the coiled tube bundle is presently under construction. Present plans include the fabrication of a  $\frac{1}{4}$  scale plastic shell and center body assembly to house the tube bundle. This model will subsequently be subjected to hydraulic testing to allow visual observation of the flow pattern and measurement of the pressure drop across the coil. If it is assumed that the friction factor is a unique function of Reynolds number, the water pressure drop data may be utilized to obtain an estimate of the sodium pressure drop in the multi-tube boiler.

Inlet Orifice Requirements. The inlet of each boiler tube is provided with an orifice in an effort to eliminate parallel channel instability and also provide a measurement of the relative flow distribution in the tubes. The orifices are designed with a  $\beta = D_{\text{orifice}}/D_{\text{tube}}$  of 0.15. This  $\beta$  ratio provides a 95 per cent loss of the differential pressure across the orifice. For the design mass velocity of  $37 \text{ lb}_m/\text{ft}^2\text{sec}$ , the orifice pressure drop is approximately 6 psi.

Summary of Boiler Design. The boiler configuration selected is shown in Figure 5. The most significant design parameters are:

Number of tubes	3
Tube I.D.	0.674 in.
Tube O.D.	0.75 in.
Tube Length	21 ft
Effective Heat Transfer Area	11 ft <sup>2</sup>
Nominal power level	240 KW
T <sub>Na</sub> in	1850°F
T <sub>Na</sub> out	1794°F
T <sub>K</sub> in	1705°F
T <sub>K</sub> out	1650°F
W <sub>Na</sub>	14 lb <sub>m</sub> /sec (max.)
W <sub>K</sub>	0.28 lb <sub>m</sub> /sec
G <sub>K</sub>	37 lb <sub>m</sub> /ft <sup>2</sup> -sec.

### Mechanical Design

General Configuration. As shown in Figure 5, the selected arrangement, based upon performance and other factors presented in Reference 3, consists of three 20 ft. long coiled tubes of 3/4-inch nominal diameter. The tubes are arranged around a 6-1/2-inch diameter center body, inside a 9-inch diameter, 60-inch long shell. Sodium flows downward between the shell and center body, across the three coiled boiler tubes. This design can be considered a single pass counterflow heat exchanger.

All structural components are to be constructed from L-605. Wherever possible, seamless pipe and tube stock is used. Welding of structural members is full penetration, crevice free. The unit will have a sodium and potassium inventory volume of 2.0 and 0.5 cubic feet, respectively. The dry boiler weight is approximately 790 lbs.

During this quarter, design of the test unit has been refined; particularly in the areas of structural members and pressure-temperature instrumentation. In addition, welding and fabrication aspects have been carefully investigated to make the unit structurally sound and readily serviceable. The test unit, as shown in Figure 5 features the following:

1. A removable boiler shell which will provide access for tube bundle repair or replacement.
2. Removable shell and boiler tube thermocouples. For reasons of thermocouple calibration and/or repair, the capability of removing and replacing thermocouples with the boiler in place is desirable.

3. Orifice plates, utilized for reasons of stability, at each tube inlet can be removed and replaced with the test unit installed.
4. An argon filled center body to displace a large volume of non-essential sodium. The argon pressure also allows this member to be fabricated from thin wall material.
5. A boiler tube support technique which will allow the tube coils to operate at a relatively low stress level even under extremely adverse test conditions.
6. A tube-to-header joint which is expected to operate at safe stress levels, even under transient rates of 50<sup>o</sup>F/min.

Structural Design. Structural components of the test boiler shown in Figure 5 were analyzed following those requirements outlined in Table 4.

The following considerations were factored into the design.

1. Static pressure stresses.
2. Boiler tube buckling criteria.
3. Thermal gradient stresses.
4. Thermal expansion and associated stresses.
5. Thermal transient stresses.

Table 5 is a summary of applicable L-605 properties used in the analysis.

When the elastic limit of the material was not exceeded, the stresses due to structural loading, static pressure, and temperature differences were determined by conventional methods of analysis (Reference 4). The short term elastic limit for L-605 at 1800<sup>o</sup>F is approximately 16,000 psi. Several cases were evaluated when the stresses exceeded the elastic range. In this analysis the determination of tube and header thermal gradients were first based upon extremely low wall to fluid temperature differences on primary and secondary sides. However, using an extreme value for the critical heat flux of  $10^6$  Btu/hr-ft<sup>2</sup><sup>2\*</sup>, the wall-to-fluid temperature differences are much larger and more realistic. As a result, the actual tube wall radial gradient will be reduced. The estimated temperature profile for this case is presented in Figure 6. Note that subcooled heating in the nozzle and tube shielded area was neglected to present a more severe than actual condition. For the case shown, the corresponding tube wall stresses will be 44,000 psi. The resulting cyclic thermal fatigue life of the tube was estimated to be in excess of 100 cycles. In this case, the thermal stresses are in the plastic range, and the only definite method of prediction is an experimental one with a full scale model under simulated conditions. In these instances, some relevant mechanical design data were based on conditions imposed upon the 300 KW single tube boiler.

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\* Current data presented in Reference 3 indicates the average critical heat flux of  $.5 \times 10^6$  Btu/hr-ft<sup>2</sup> was obtained in the nucleate region of the single tube boiler. To be conservative a factor of 2 was applied to this value.

In general, structural members were sized for maximum continuous loop pressure and temperature over a period of 1000 hours operation. Safety factors of 3 and 2, based on the 1000 hour rupture strength, were used respectively on critical (hazardous) and non-critical members. A hazardous member is defined as any structural member which, if failure occurred, would cause direct exposure to air with the possibility of fire. A non-critical member is one which, if failure occurred, would result only in intermixing of primary and secondary fluids.

At normal operating conditions, the primary fluid pressure is always greater than that of the secondary. Therefore, external pressure and axial compression loads were investigated in regard to the limits than can be expected for tube failure due to elastic instability (Reference 5). In all cases the compressive load and external pressure which will be imposed on the boiler tube straight section were significantly less than the theoretical limits.

Stresses resulting from exceptionally high temperature gradients through boiler tube and shell members were investigated. The resulting surface stresses obtained from temperature gradients will be short term only and effects will be come negligible due to plastic deformation at operating temperatures. Primary concern was the residual effects of the stress levels imposed upon structural members during cool down when the L-605 must pass through a 1400-1600°F low ductility region. The significance of these stresses becomes important only in cyclic fatigue life and structural deformation.

Due to the thermal expansions during loop heat-up, it has been planned to install, external to the boiler shell, pipe line expansion sections to minimize boiler shell and nozzle loads.

Within the boiler unit, the most interesting thermal expansion was that between the boiler shell and tubes. This expansion will be safely absorbed in the boiler tube coils for the most severe test conditions. The tube stress will vary proportionally to the differential expansion. These stresses will range from 390 to 1,170 psi, from normal to the worst test mode.

During start-up and shut-down, fluid transient temperature rates of 20<sup>o</sup>F/min, are expected. At a "dump" condition, temperature transients as high as 50<sup>o</sup>F/min could occur. These conditions were investigated for boiler tube and shell members (Reference 6). Of all structural members the tube-to-header joint is most likely to have high stresses for these conditions.

Prior investigations have pointed out that the region of critical stress concentration exists at the tube-to-header welds in most shell-and-tube designs during transient conditions. A boss extending 1/4-inch to 1/2-inch with a smooth transition from header to tube will reduce stress concentration at the welds. The stress level will be additionally reduced by decreasing the temperature difference between the header and tubes with thermal shields.

For the above considerations, a summary is presented in Table 6 indicating the recommended design thicknesses and commenting on the structural members A through R which are shown in Figure 5.

Instrumentation Design. A substantial effort has been put into the design of temperature instrumentation. Due to the severity of service, quantity of thermocouples required, and past experience in this area, it was decided to proceed with the instrumentation design in a cautious manner. It was considered desirable to develop a design in which the sheath of the thermocouple would be doubly contained in a sealed well. This is required in order to eliminate any direct contact between the thermocouple sheath and liquid metals and also to provide a back up containment in case of thermocouple well and sheath failure. As a result, a 0.060-inch diameter sheathed thermocouple was designed that is contained in a 3/16-inch outside diameter well of 0.050-inch wall thickness. The well and sheathed thermocouple will be held in the boiler shell by using swagelock fittings for mechanical sealing. A typical thermocouple assembly is shown in Figure 7.

Representative samples of thermocouple tip and fittings are being constructed for evaluation of weld fabrication and mechanical arrangement. It is expected that this arrangement will allow for removal and insertion of thermocouples while the boiler remains in place.

Boiler Installation. An investigation was made in regard to fitting the unit into the 300 KW facility. (A later phase of the 300 KW program will require a separate superheater unit in series with the multi-tube boiler. This aspect will be discussed in a later section of this report.)

It is planned to install the test boiler in the same relative location as the single tube boiler. At this time, modification to the 300 KW loop piping, several support hangers and dump tanks are anticipated. It is desirable from a time and cost standpoint to make these modifications compatible with the future superheater location.

Status of Drawings, Procurement and Fabrication. The detail, assembly, and instrumentation drawings have been completed.

Procurement has placed orders on approximately 95% of the raw material. It was necessary to re-negotiate several items in regard to price and delivery. As a result, our current estimate indicates that all raw material will be delivered on or before June 30th.

Final quotations for the forged reducing nozzles on each end of the test unit were very high. The vendor was contacted to investigate ways of reducing this cost, however, no immediate cost reduction could be achieved. The items were ordered at that price. As a result, it became more apparent that the application of casting techniques for L-605 must be investigated to replace costly forged and/or machined fittings.

A detail cost estimate to machine and fabricate the test boiler has been prepared. This information is available and was presented in the meeting at NASA-Lewis Research Center, April 2, 1964.

Sample details of L-605 thermocouple wells have been machined and have been made ready for welding studies. These sample thermocouple wells were welded successfully. Based on this experience, the thermocouple configuration has been decided and is reflected in the design.

Due to the complex nature of the coil configuration, preparations have been made to make three 1/4 scale model boiler tubes. These will be used to investigate boiler assembly technique and later for hydraulic testing.

#### Instrumentation Planning

Introduction. Current tube bundle boiler instrument planning can be divided into two categories; (1) those instruments which would enable the overall performance of the boiler as a component to be evaluated, and (2) those instruments which would enable fundamental heat transfer information to be obtained. These categories are discussed in detail in the following section.

Component Performance Evaluation. The current planning provides for the measurement of inlet and outlet bulk temperatures of both sodium and potassium streams, as well as the flowrate of each stream. In addition, potassium inlet and outlet pressure gages will be provided. These measurements are sufficient to calculate the overall heat transfer coefficient, the exit quality, and the boiler pressure drop.

The tube bundle boiler may prove to be unstable in certain areas of operation since it is possible that the three tubes may not operate equally.

Present planning calls for a pressure difference gage to be placed across each of the three boiler tube inlet orifices. These gages will allow the relative distribution of flow among the three tubes to be determined during boiler operation.

Local Measurements. Current instrument planning provides for two axial rows of thermocouples penetrating the boiler shell and extending into the sodium stream. In addition, circumferential rings of these thermocouples are provided at three axial stations. The purpose of the thermocouple rings will be to detect circumferential variation of sodium temperature due to distortions or eccentricities in the center body and/or boiler tube position. The heat transfer region of subcooled heating is not easily determined from the sodium temperature, but the regions of nucleate boiling and film boiling can be approximately determined from the thermocouple indications along the shell length. The subcooled heating region is considerably more pronounced in the potassium stream, thus additional thermocouples positioned inside the three boiler tubes and immersed in the potassium are also contemplated.

The instrumentation specified above should enable the average heat flux in each of the heat transfer regions to be calculated. It is expected that the immersed sodium thermocouples will scatter due to the complexity of flow and temperature distribution in the sodium stream. Only if the scatter is small, will it be possible to determine the variation of heat flux with length within one or more of the heat transfer regions.

Two rows and three rings of thermocouples placed on the outer boiler shell wall will also be provided. These latter thermocouples, by comparison with the thermocouples immersed in the sodium, will provide data for an evaluation of the accuracy of boiler shell thermocouples when used to determine temperature gradients and transition points. A desirable duplication of measurement is thereby provided.

Thermocouples placed upon individual boiler tube walls were considered in the instrument planning but are not recommended. Boiler tube wall thermocouples conceptually would be used to determine transition points between the three regions of heat transfer in each boiler tube and to obtain point values of sodium and potassium heat transfer coefficients. The temperature errors in tube wall thermocouples, due to errors of attachment and sheath thickness are large in comparison with the temperature changes that would have to be detected. At the design point of the tube bundle boiler, which is 1650°F exit temperature and 100 percent quality, the change of potassium temperature in the nucleate boiling region would be only about 10°F. The error in boiler wall thermocouples caused by variations in sheath thickness alone has been calculated to be 5°F. In addition, due to the helical design of the boiler tubes, the liquid phase will be forced to one side in boiling, thus the heat flux and temperature will vary circumferentially around each tube. These considerations discourage tube wall thermocouples.

## Superheater Design

### Thermal and Hydraulic Design

Preliminary Calculations. Present planning includes the design and fabrication of a superheater to be installed in the 300 KW facility downstream of the multi-tube boiler. Preliminary calculations have been carried out to estimate superheater size requirements. The following criteria were defined;

$w_{Na}$	=	14 lb/sec
$w_K$	=	0.28 lb <sub>m</sub> /sec
$T_{K in}$	=	1650°F
$X_{in}$	=	0.98 to 1.0
Degree of Superheat	=	50°F
$C_p$	=	0.41 Btu/lb <sub>m</sub> °F

Using these criteria, the power level of the superheater was set at approximately 10 KW. Potassium heat transfer coefficients were computed using the conventional Nusselt equation (Reference 7):

$$N_{Nu} = 0.021 N_{Re}^{0.8} N_{Pr}^{1/3}$$

The sodium and the wall resistances were assumed to be negligible due to the large resistance of the potassium in film boiling. Shown in Figure 8 is the potassium heat transfer coefficient as a function of number of tubes and nominal tube diameter. The required tube lengths shown in Figure 9 were computed using the values of Figure 8. The remaining item to be considered is the superheater pressure drop. Shown in Figure 10 are the system pressure drops conformal with the lengths given in Figure 9. It should be noted that this

is friction drop only, and does not include the pressure drop due to acceleration of the fluid. Inspection of Figure 9 indicates that very little is gained in length by using more than 20 tubes. Also, Figure 10 indicates that the pressure drop for 20 tubes becomes excessive for smaller diameter tubes.

Thus, the superheater is recommended to consist of nineteen (19) 0.5-inch diameter tubes, 70 inches in length. For this design the friction pressure drop is 0.7 psi.

A FORTRAN computer program is being developed to provide a parametric design of a superheater with boiler carry-over. The program is capable of handling any arbitrary surface within the tubes. Input consists of boiler power level, boiler exit quality, primary and secondary temperature levels in the superheater, and tube geometry. Output includes superheater size, exit Mach number, and acceleration and friction pressure drop for up to 20 values of the number of tubes.

Summary of Preliminary Superheater Design. The tentative superheater configuration is shown in Figure 11. The most significant parameters for this design are:

Number of tubes	19
Tube I.D.	0.44 in.
Tube O.D.	0.50 in.
Tube Length	70 in.
Effective Heat Transfer Area	12.7 ft <sup>2</sup>
Power Level	10 KW
T <sub>Na,in</sub>	1855°F
T <sub>Na,out</sub>	1850°F
T <sub>K,in</sub>	1650°F
T <sub>K,out</sub>	1700°F
Inlet Quality	.98 to 1.0
W <sub>Na</sub>	14 lb <sub>m</sub> /sec
W <sub>K</sub>	0.28 lb <sub>m</sub> /sec

### Mechanical Design

General Configuration. The proposed superheater unit, as shown in Figure 11, will be a "hockey stick" configuration containing nineteen 1/2-inch diameter, 70-inch overall, long tubes. Within a 5-inch diameter shell, the tubes are arranged in a close spaced triangular pitch pattern. External to the tubes, sodium flows parallel, single pass and counterflow to the potassium within.

Design Considerations. Only preliminary efforts have been utilized in the area of investigating structural design and fabrication. Preliminary design specifications are presented in Table 7. Upon approval of these requirements, basic structural components will be investigated in a manner similar to that used on the multi-tube boiler.

All components will be constructed from L-605. Wherever possible, seamless pipe and tube stock will be used. Welding throughout will be full penetration, crevice free.

From preliminary calculations, tube-to-shell thermal expansions can be safely absorbed in the "L" section of the superheater tubes.

Due to the compactness of the tube bundle and quantity of tubes required, an internal tube-to-header weld joint is utilized. From the aspect of structural integrity and fabrication of this multi-tube bundle, it appears to be a very desirable arrangement.

Instrumentation. In this design tube or shell instrumentation is not being considered. Pressure and/or temperature instrumentation is planned for the superheater inlets and outlets only. It is felt that this will be adequate to determine superheater overall performance, provided that the temperature change is sufficient to be measurable.

Installation. As mentioned earlier, installation of both the multi-tube test boiler and the test superheater into the 300 KW facility have been investigated. The superheater, as described by the envelope shown in Figure 11 can be installed in the potassium boiler outlet pipe run with no major difficulties. To do this, the anticipated modifications will be in primary loop piping and additional support hangers. A sketch of this superheater and boiler installation arrangement is shown in Figure 12.

Status of Drawings, Procurement and Fabrication. A preliminary design drawing has been prepared and presented to NASA.

No procurement action has taken place. It is planned to make cost and delivery inquiries in regard to the 1/2-inch diameter tube and shell members. Based upon multi-tube boiler delivery dates, the longest lead time item is estimated to be five to six months.

A cost estimate was prepared for material and fabrication of a 300 KW test superheater. This was presented in a meeting held April 2 at NASA-Lewis Research Center.

Primary concern in the area of fabrication is the tube-to-header weld joint. It would be desirable to make samples of this joint with some "bread-board" type welding unit, to get an indication how to proceed in the design area.

#### Status of Data Reduction

##### Introduction

The heat transfer data obtained in the 300 KW facility during the period December 26 ~ 31, 1963, are reported. These values are the latest data obtained up to April 1, 1964, thus data reduction for the 300 KW facility is now up to date with the exception of about 170 transient boiling runs obtained about May 1963 and also some liquid-liquid runs.

The boiling data presented in this report were obtained with the nominal 1.0-inch L-605 boiler tube with a 2-inch pitch helical insert and includes 65 runs. The test results encompass the following range of variables:

Sodium flow rate, lbs/sec.	6.42 to 11.3
Potassium flow rate, lbs/sec.	0.0573 to 1.897
Potassium exit temperature, °F.	1353 to 1742
Sodium inlet temperature, °F.	1400 to 1863
Potassium Quality, %	0 to 100
Potassium Subcooling, °F.	132 to 876
Net heat transferred, Btu/sec.	4.61 to 167

Several calculated quantities for each run, such as the overall heat transfer coefficient, potassium exit quality, inlet subcooling, etc. are presented in addition to the reduced data.

The presentation of the data is made in five parts. These are:

1. Description of instrumentation and test conditions.
2. Column headings.
3. Calculational procedure.
4. Comments concerning the tabulated data.
5. Tabulated data.

The column headings provide a description of the quantity referred to in the tabulated data and also are utilized as the nomenclature section for the calculational procedures.

#### Description of Instrumentation and Test Conditions

All of the reduced data reported are boiling runs. The location of all instrumentation other than that discussed specifically below is detailed in Reference 8.

Boiler. The data were obtained with a 1.0-inch O.D., 0.038-inch wall welded L-605 boiler tube. The boiler tube length between thermal shields is 67.5-inches. The tests were conducted with a 2.0-inch pitch helical insert instrumented with seven thermocouples. The insert and its instrumentation are detailed in Figures 1 and 2 of Reference 9. The column headings of the insert thermocouples include their locations as illustrated by the following example: B125 = boiler insert thermocouple located 25-inches from the boiler reference plane B as shown in Figure 2 of Reference 9.

Eight grounded thermocouples were placed in each of seven rings at seven different axial locations along the outer boiler shell for the data reported. The junctions of these grounded thermocouples were attached directly to the boiler shell wall at several axial positions.

The average temperature at each axial position is reported in the data tabulation, the averages of the grounded and ungrounded thermocouples being listed separately. The axial positions of the boiler shell temperatures listed are given in the column headings as illustrated in the following examples:

GSBW47 = Grounded boiler wall thermocouple 47-inches from boiler reference plane.

USBW47 = Ungrounded boiler wall thermocouple 47-inches from boiler reference plane.

Potassium and sodium bulk inlet and outlet temperatures as well as potassium inlet and outlet pressure were measured as in previous tests.

Condenser. None of the horizontal condenser inner wall thermocouples were operative during these runs. Several of the air annulus thermocouples were inoperative. The temperatures indicated by the working air annulus thermocouples are presented, and labeled according to their axial and radial positions as illustrated in the following example:

9HA21 - Horizontal condenser air annulus thermocouple located radially at 9 o'clock and located axially 21-inches from reference plane HC. The 12 o'clock position is

up, looking into the potassium flow. The inlet air nozzles are located 3-inches from reference plane HC and the outlet air nozzles are located 121-inches from the same plane. (Reference plane HC is shown in Figure 21 of Reference 8.)

The inlet and outlet potassium temperature in the vertical condenser and the outlet potassium temperature in the horizontal condenser were measured as in previous tests..

Column Headings. The column headings are given in Table A-1 of Appendix A.

Calculation Procedures used on the 300 KW Facility. The calculation procedures are given in Appendix B. The nomenclature used is that given by Table A-1 of Appendix A.

Comments Concerning the Tabulated Data. The helical insert failed after the run at 1150 hours on 12/28/63 for the data presented. The boiler insert temperatures following this run are not presented.

Calibrations performed before and after the runs presented showed both potassium boiler pressure gages to have suffered zero shifts during the test series. In addition, the outlet potassium pressure gage was found to have a diaphragm leak. The data presented for boiler pressure and pressure drop should therefore be used with caution.

The digital readout device malfunctioned for the runs taken at 0010 and 0210 hours on 12/30/63 and data for these two runs should be disregarded.

Tabulated Data. The 300 KW data are presented in Tables A-2 and A-3 of Appendix A.

Status of Data Evaluation

Two-Phase Pressure Drop

A very useful means of presentation of two phase pressure drop data is the procedure used by Martinelli, where the ratio of two-phase to single phase pressure drop is correlated against quality. Unfortunately, however, the Taylor gauges installed on the 300 KW boiler are not sufficiently accurate to determine the liquid potassium pressure drop in the boiler, since the liquid pressure drop is very small compared to the boiling pressure drop. In order to circumvent this difficulty, the friction factors of the test boilers with their inserts have been determined by measuring water pressure drops, utilizing a differential monometer connected to the Taylor gauge pressure taps. Treating the friction factors so obtained as unique functions of the Reynolds number allows the liquid potassium pressure drops to be calculated for the various two-phase test conditions. The temperature variation of the potassium along the boiler length is neglected in this calculation.

The following derivation defines the procedure by which liquid potassium pressure drop can be obtained from water pressure drop measurements made on a given boiler tube.

If the Reynolds numbers for potassium and water are the same, the following relation must hold:

$$\frac{(N_{Re})_K}{(N_{Re})_W} = 1.0 = \frac{v_K \rho_K \mu_W}{v_W \rho_W \mu_K} \quad (1)$$

$$\therefore \frac{v_K}{v_W} = \left(\frac{\rho_W}{\rho_K}\right) \left(\frac{\mu_K}{\mu_W}\right) \quad (2)$$

At the same Reynolds number, the friction factor for water and liquid potassium are equal thus:

$$\frac{f_K}{f_W} = 1.0 = \frac{\Delta P_K / \rho_K v_K^2}{\Delta P_W / \rho_W v_W^2} \quad (3)$$

$$\therefore \frac{\Delta P_K}{\Delta P_W} = \frac{\rho_K}{\rho_W} \left(\frac{v_K}{v_W}\right)^2 \quad (4)$$

Substituting  $v_K/v_W$  from Equation (2) into Equation (4), the final result is obtained:

$$\frac{\Delta P_K}{\Delta P_W} = \frac{\rho_W}{\rho_K} \left(\frac{\mu_K}{\mu_W}\right)^2 \quad (5)$$

It is seen from Equation (5) that  $\Delta P_K/\Delta P_W$  is only a function of physical properties. Since the water pressure drop data were obtained at constant temperature,  $\Delta P_K/\Delta P_W$  is a function only of the potassium temperature. This ratio has been elevated and is presented in Figure 13 as a function of potassium temperature.

Water pressure drop data have been obtained from the L-605 boiler tube being used in current tests, with and without the 2-inch pitch helical insert. These data are presented in Figures 14 and 15 as pressure drop vs. Reynolds number.

Figures 13, 14 and 15 can be used to obtain the liquid potassium boiler pressure drop for any operating temperature. The Martinelli ratio of two-phase to single phase pressure drop can therefore be obtained by measurement of the two-phase pressure drop only.

Initial values of the two-phase multiplier of 120 at 40% quality have been obtained with the helical insert. Evaluation of the boiling pressure drop results is continuing.

#### Boiling

Evaluation of 300 KW boiling data continued during this reporting period. The current objective of boiling data evaluation is to eliminate or reduce the effects of inlet subcooling and thereby provide a comparison of boiling heat transfer with and without insert.

### Test Planning

A new test plan for the next series of 300 KW tests has been written and is presented following. Sufficient liquid-liquid runs are specified to attempt separation of the sodium and potassium liquid heat transfer coefficients. The individual liquid coefficients are needed for evaluation of the boiling data. Additional liquid-liquid runs are specified to supply data for an approximate calibration of the sodium and potassium magnetic flowmeters against a known air flow rate to the horizontal condenser. Thermocouple calibration runs are also specified.

Evaluation of 300 KW data has been hampered in the past by the necessity of separating the effects of the large number of variables affecting loop operation. The test plan presented for the boiling runs specifies as many of these variables as possible to be held constant.

Each boiler tube with its insert will be subjected to pressure drop testing with water before installation in the loop. The water tests will provide single phase pressure drop data to which the two phase potassium pressure drops can be compared.

## Test Plan, 300 KW

The testing for each boiler tube and insert is divided into the following consecutive phases:

### Phase I - Pre-installation testing:

#### A. Reference Boiler Tube Pressure Drop:

Before installation in the loop, each boiler tube with its insert in place will be subjected to pressure drop studies with water. The water mass flow-rate shall be varied (in twenty steps) from zero to eight lb/sec which corresponds to the maximum potassium Reynolds number obtainable in the loop. The water temperature shall be monitored to  $\pm 5^{\circ}\text{F}$ , and the pressure drop across the tube shall be determined within  $\pm 0.1\text{-inch}$  of water. This test will be run on the assembled boiler with inlet and outlet pressure measured at the taps to be used for pressure measurements during loop operation.

#### B. Primary and Secondary Thermocouple Calibration:

Before loop operation with each test section at least one of the thermocouples in the primary inlet and secondary outlet wells shall be calibrated in a melting point apparatus.

### Phase II - Calibration Runs:

#### A. Flushing Runs:

Data for the calibration Runs B and C, following, will be obtained during the flushing operation. This operation is

necessitated by the internal failure of the test boiler bellows in the last series of tests.

The flushing operation will consist of charging the primary and secondary dump tanks with fresh charges of alkali metal, filling the test loops, circulating for four hours, dumping the loops and then draining the dump tanks. This operation will be performed twice in each loop.

Samples will be taken before and after each flushing to determine the level of contamination which must be less than 0.5% in Na and K. The dump tanks will then be filled with fresh charges of alkali metal, the loops filled and circulated for four hours, and then dumped. A sample will be taken from each dump tank for oxygen analysis. If the results of these analysis show that the oxygen content is less than 50 ppm, the loop will be ready for boiling operation. Otherwise hot trapping for 48 hours at 1200°F will be completed prior to boiling.

B. Calibration of Primary Thermocouples and Determination of Boiler Heat Losses:

In this test series, the secondary will be drained and evacuated. The following test will then be conducted at average primary temperatures of  $1100 \pm 50^{\circ}\text{F}$  and  $1600 \pm 50^{\circ}\text{F}$ . The primary will be circulated at a flowrate such that the temperature difference

of the primary across the boiler is about 10°F. Another data point at this same average temperature  $\pm$  15°F will be obtained with the primary flow increased to its maximum.

C. Relative Calibration of Secondary Boiler Thermocouples and Primary Flowmeter:

The following liquid-liquid tests shall be performed at average secondary temperatures of 1100  $\pm$  50°F and 1600  $\pm$  50°F.

The secondary stream will be circulated at approximately 2 lb/sec, and the primary flow rate shall be adjusted to give a sodium temperature difference of 30°F across the boiler. The secondary flow rate will then be reduced by a factor of five, and the primary flow rate will be reduced to keep the primary temperature difference at 30°F.

Phase III - Liquid-Liquid Runs:

A. Wilson Plot:

The following data will be obtained at 1100  $\pm$  50°F and 1600  $\pm$  50°F.

The primary flow rate shall be raised from zero to its maximum in six steps with the secondary flow rate maintained at 2 lb/sec.

B. Additional Liquid-Liquid Runs:

Any additional liquid-liquid tests felt necessary for specific test sections will be performed in this phase.

Phase IV ~ Boiling Runs:

The following tests will be carried out for secondary outlet temperatures  $1700 \pm 50^{\circ}\text{F}$ ,  $1500 \pm 50^{\circ}\text{F}$  and  $1200 \pm 50^{\circ}\text{F}$ .

1. For Items 2, 3 and 4 following, the primary flow rate will be maintained constant to  $\pm 5\%$ , at a value low enough to give at least a  $5^{\circ}\text{F} \Delta T$  across the boiler in the primary for all points.
2. The secondary outlet temperature will be maintained constant within  $\pm 10^{\circ}\text{F}$  for Item 3 following.
3. For each of three values of secondary flowrate, the total heat transferred in the boiler will be increased in five steps with the maximum boiler load for the particular flowrate being established by loss of load in the boiler caused by film boiling or facility limitations. The primary temperature will increase as boiler load is increased under these conditions. The secondary flowrate will be maintained constant to  $\pm 10\%$  while boiler load is varied.
4. Repeat steps 2 and 3 for a different (lower) value of the primary flowrate for only one (the most informative) value of secondary flow.

After the above tests are completed, a series of data will be taken which concentrate in the most interesting areas of the data map established above, or fill in areas not totally covered.

Phase V - Time Dependence Tests:

Certain portions of Phase III will be repeated to determine any effects of time upon the experiment results.

### III. 100 KW PROJECT

#### Introduction

The 100 KW facility is a single loop system used to study heat transfer to boiling alkali metals at temperatures up to 2200°F. The electrically heated boiling test section is a vertical section of 3/4 inch schedule 80, Cb-1%Zr pipe. Thermocouples are attached along the outer wall of the test section at intervals of approximately 2 inches. A preheater, located upstream of and in series with the test section is used to control the boiler inlet sub-cooling. The working fluid is potassium.

#### Status of Loop and Test Section

During the last reporting period, the 3/8 inch test section (including the mixer) was cut from the loop and replaced with a new 3/4 inch schedule 80 test section. The problems associated with measurements of temperature and power in the 100 KW facility were discussed in Reference 3. In an attempt to eliminate these problems, the following instrumentation changes were made before resuming operation:

1. The mixer at the test section outlet has been removed.
2. Thermocouple wells have been installed at the test section inlet and outlet.
3. The facility has been completely reinstrumented with W3%Re vs. W26%Re thermocouples.
4. A polyphase wattmeter has been obtained for power measurement.

Instrumentation details are discussed in Section VII of this report.

Since the size of the test section was increased, a new radiation case was required. The heat loss from the surface of this case was measured during January. Final instrumentation was completed on February 4, 1964 and boiling operation began on February 6.

On the first date of operation, all attempts to obtain stable boiling conditions were fruitless. After circulating liquid potassium through the loop overnight, boiling operation was resumed on February 7 and stable boiling conditions were obtained without difficulty. Since the test section was new, the stability problems on the first day of operation may have been due to non-wetting of the test section.

The overall system stability characteristics of the 100 KW facility were discussed in Reference 3. The present system appears to have about the same characteristics, i.e., when flow and pressure are held constant and power is increased, the system first becomes unstable when boiling begins, then becomes stable and remains stable over a limited range of power and finally becomes unstable again. It was stated in Reference 3 that after the "second instability" occurs, the system remains unstable up to the maximum power limit of the heater. With the new test section, it has been possible (on one occasion) to go beyond the second instability and obtain stable boiling data at higher boiler powers.

The failure rate of the new tungsten 3% rhenium vs. tungsten 26% rhenium thermocouples appears to be significantly lower than that of the thermocouples

formerly used, resulting in a minimum of "down time" for thermocouple repair. A total of 97 stable boiling points were obtained during the present reporting period, increasing the hours of operation from 2625 to 3381.

#### Status of Data Reduction

A new computer program, written to reduce the data from the reinstrumented facility, has been checked out and all data taken during the present reporting period have been reduced.

#### Status of Data Evaluation

##### Heat Loss Tests

The 100 KW test section is insulated with radiation shields enclosed in a stainless steel case. The purpose of the heat loss tests was to determine the relationship between heat loss and temperature of the outer surface of the radiation case. During the tests, the case enclosed the heater but not the test section pipe. Consequently, all the power supplied to the heater was lost through the case. Measurements of the electrical power input and the corresponding steady-state case temperature resulted in a direct correlation of heat loss as a function of temperature. The temperature used in the correlation is a weighted average,  $\hat{T}$ , of the six measured values:

$$\hat{T} (\text{°F}) = \left( \frac{\sum_{i=1}^6 T_i^4}{6} \right)^{1/4} - 460 \quad (1)$$

where the  $T_i$  are the six measured temperatures in degrees Rankine. The results of this test are plotted in Figure 16 and again in Figure 17.

Three or four data points were taken at each power level to check reproducibility, which was very good.

The results of heat loss tests on the preheater case are presented in Figure 18.

#### Flowmeter Calibration

Liquid data taken during this quarter were used to calibrate the E.M. flowmeter. The measured flow rate was compared with the flow calculated from a heat balance across the test section. The result of these tests are presented in Figure 19. The calculated flow was obtained from:

$$W_C = \frac{q}{H_{out} - H_{in}} \quad (2)$$

where,

$W_C$  = Calculated flow, lb/sec

$\dot{q}$  = Net boiler power, Btu/sec

$H_{out}$  = Liquid enthalpy at test section outlet, Btu/lb.

$H_{in}$  = Liquid enthalpy at test section inlet, Btu/lb.

As can be seen in Figure 19 the flow rate indicated by the flowmeter is consistently low compared to the calculated flow rate. The results of these tests were used in reducing the boiling data by correcting the measured flow rate. The flow rate then becomes:

$$W = 1.32 W_m \quad (3)$$

where,

$W$  = corrected flow rate.

$W_m$  = measured flow rate.

This flowmeter calibration will be checked periodically.

#### Boiling Potassium Data

Table 8 shows the test plan which was followed during February and March. Holding flow and pressure constant, the boiler power was increased in increments of approximately 0.5 KW while the preheater power was decreased in increments of 0.5 KW. This procedure was continued until the preheater was turned off. At this point, the boiler power alone was increased in small increments until unstable boiling began or until the heater capacity was reached at five pressure levels with the flow held constant.

The results of the boiling tests are tabulated in Appendix C (Tables C-3, C-4, and C-5). An instrumentation list (showing test section thermocouple locations) along with a table key are also given in Appendix C, (Tables C-1, and C-2). The ranges of variables covered in these tests are:

Heat flux, Btu/hr-ft <sup>2</sup>	45,600 to 163,400
Quality, %	3 to 37
Boiler Exit Temperature, °F	1648 to 1844
Mass Velocity, lb/hr-ft <sup>2</sup>	76,000 to 87,000

Figure 20 is a plot of the local heat transfer coefficient at the boiler outlet (just inside the heated zone) as a function of boiler exit quality. The flow rate is constant for these data and curves are drawn through points of constant pressure. As the heat flux was increased by decreasing the preheater power and increasing the power into the test section while holding flow and pressure constant, the quality remained essentially constant for the first few points.

After the preheater power was reduced to its minimum setting, further increases in boiler power resulted in: 1) an increase in test section exit quality and, 2) an increase in boiling length. There may be an effect of changes in the boiling length on the heat transfer coefficient measured at the test section exit, analogous to the familiar entrance length to diameter ratio effect in single phase flow, for which the local heat transfer coefficient is a function of the distance from the entrance of the duct. Since an increase in test section power causes changes in quality and  $L'/D$  (where  $L'$  is the length in bulk boiling and  $D$  is the inside diameter of the duct), the effects of heat flux, quality and  $L'/D$  are confounded for the data presented in Figure 20. Consequently, the general trend of increasing  $h$  with increasing  $x$  (at constant flow rate and pressure) indicated in Figure 20, could be misleading because increases in  $x$  were accompanied by increases in heat flux and  $L'/D$  in these tests. This can be seen more clearly by considering the definition of the heat transfer coefficient:

$$h = \frac{q/A}{T_{wi} - T_b} \quad (4)$$

where,

$$\begin{aligned} q/A &= \text{heat flux, Btu/hr-ft}^2 \\ T_{wi} &= \text{inside wall temperature, } ^\circ\text{F} \\ T_b &= \text{bulk fluid temperature, } ^\circ\text{F} \end{aligned}$$

For constant flow rate and pressure, the wall-fluid temperature difference will, in general, be a function of heat flux, quality and L/D:

$$T_{wi} - T_b = F(q/A, x, L'/D) \quad (5)$$

combining (4) and (5):

$$h = \frac{q/A}{F(q/A, x, L'/D)} \quad (6)$$

In these tests, changes in q/A caused changes in x and L'/D. Thus, the effects of q/A, x and L'/D are confounded in the determination of h.

The heat flux used in the determination of h is obtained by dividing the net boiler power by the inside area of the test section. This, of course, implies that the heat flux is uniform along the test section. Since the test section wall temperature varies along the length, due to the variation in bulk fluid temperatures, the "sink" temperature for radiation is changing and the heat flux might be nonuniform. An estimate of the variation of heat flux was presented in Reference 8 for a tube wall temperature variation of 200°F. In some cases the test section wall temperature varies as much as 1000°F over its length of the test section.

Assuming a uniform tungsten rod temperature of 5000°F, an inlet test

section wall temperature of 1200°F and an outlet wall temperature of 2200°F, the heat flux variation is estimated to be 5%. A more complete analysis, which allows variations in tungsten rod temperature, is in progress.

#### Facility Modification

Objectives. The local heat transfer data obtained in the present 100 KW facility include:

q/A	=	heat flux, Btu/hr-ft <sup>2</sup>
T <sub>wi</sub>	=	pipe wall temperature, °F
T <sub>b</sub>	=	bulk fluid temperature, °F
W	=	flow rate, lb/sec.
x	=	Quality

In the current tests, W and T<sub>b</sub> are held constant while q/A is varied. Hence, q/A is the independent variable in these tests and since quality at the boiler outlet is a function of q/A, there are two dependent variables: T<sub>w</sub> and x. As discussed in Reference 3, the maximum quality that can be achieved in the present system is limited by heater capacity and system stability. Due to the limitations in the present system, it has been proposed that the 100 KW facility be modified in order to:

1. Provide an additional degree of freedom, that is, a better control of the independent variables such that systematic changes can be made while holding all but two of the variables constant.

2. Increase the range of variables that can be studied.

Description. As described in Reference 3, instabilities originating in the boiling test section often initiate oscillations in the dump tank causing the system to go unstable. Operating experience with the 300 KW and the original 50 KW facilities indicates that the isolation of the dump tank from the loop can extend the range of stable operation. Therefore, in an attempt to extend the range of stable operation in the 100 KW loop, a valve will be installed between the dump tank and the loop.

Figure 21 is a schematic showing the proposed method of modifying the loop. The present preheater will be replaced by a preboiler in series with the test section. Power to the preboiler and test section will be controlled independently. The function of the pre-boiler is to control the exit quality of the pre-boiler. With this scheme, it is possible to hold three of the parameters discussed above constant while the other two are varied.

The pre-boiler will consist of a helically wound section of pipe with a radiant heater in the core of the helix and the test section a straight vertical section of pipe similar to the present boiler. Electrical power to the preboiler will be supplied by the existing equipment which is capable of delivering 100 KW of gross electrical power. New equipment, capable of delivering 50 KW of gross electrical power, will be used to supply the test section.

Based on considerations of space limitations within the vacuum chamber, heat transfer area requirements and material availability, the following pipe sizes have been selected:

	<u>O. D.</u>	<u>I. D.</u>	<u>Heated Length</u>
Preboiler	0.937"	0.723"	100"
Test Section	Various Sizes		40"

Assuming the heat losses in the pre-boiler and test section to be 20% of the gross power input, the maximum net power will be:

Preboiler	=	80 KW
Test Section	=	40 KW

Figure 22 is a plot of the pre-boiler exit quality as a function of flow with constant power assuming saturated liquid temperature at the inlet of the pre-boiler. The lowest curve is the capacity of the present preheater. In the past, stable boiling operation below 0.025 lb/sec was not obtained. For this flow rate the calculated test section inlet quality is limited to about 25% (Figure 22). The actual value is lower due to the sub-cooling caused by the condenser. Figure 22 indicates that a greatly increased range of inlet conditions can be obtained by installation of the pre-boiler.

#### IV. 50 KW PROJECT

##### Status of Loop and Test Section

Except for 100 hours of operation during the first week in March, the facility has been shut down for repairs throughout the quarter, due to test section failure last December and subsequent failure of the potassium loop MSA pump. The defective pump will be replaced by an available second hand pump. A new pump is on order with delivery promised in June. The repaired original test section has been installed. Unfortunately, some of the thermocouples in this test section are now inoperative; hence, usage of the test section is limited. A replacement test section should be available in April.

Installation of the new boiler rated at 60 KW was completed. This boiler consists of twenty-four 5/8-inch O.D. x 20-inch long immersion heaters (each rated at 2.5 KW at 230 V) welded into a 12-inch tee. Three additional variable transformers rated at 10 KW each have been installed in the control console, thus the boiler capacity is increased to 60 KW. The line heaters have been modified to allow operation of them, independent of the calorimetric flowmeter.

Construction of a new test section began immediately following the test section failure of December 7, 1963. A new method of manufacture of the thick walled nickel tube thermocouple holes, which uses a brazing rather than a welding technique, was attempted. This technique was used to

eliminate the test section failures caused by sodium leakage through the seal welds of the sheet inserts into the tube slots. This is discussed in Section VIII of this report.

The 50 KW facility started operation on February 28, 1964, with a repaired rather than a new test section because of the difficulties encountered with the brazing of the new test section as presented in Section VIII of this report. During loop checkout on February 1, 1964, before the installation of the test section, the potassium loop MSA pump was found to have failed beyond repair due to a leak between the pump duct and electrode. The failure probably occurred during the previous period of loop operation, i.e., November 19 to 30, 1963, when potassium liquid flow could not be maintained (Reference 3). Sodium and potassium thermocouple calibration runs were made at 1010°F and 1210°F, respectively on February 29, without the potassium pump in the loop, in preparation for condensing operation. The potassium loop appeared to be less stable during vapor calibration than during the previous vapor calibrations when a pump was available to overcome the flow control valve pressure drop.

Condensing operation began on March 3 without a potassium pump in the loop and, therefore, considerable stability problems were encountered with only 15 KW boiler electrical input and with the potassium fluid temperature at the condenser inlet between 1150 and 1400°F. Problems were also encountered maintaining the potassium liquid vapor interface at or slightly below the condenser exit.

Potassium flow pulsations were observed that were plus or minus five times the average flow level of about 40 lbs/hr. and the temperature pulsations at the condenser inlet were about  $\pm 3^{\circ}\text{F}$ . Efforts were made to minimize these flow and temperature pulsations by means of the liquid and vapor flow control valves with some success, but difficulties were encountered in maintaining the liquid level at or below the condenser exit.

For these reasons the facility was shut down to await installation of a second hand EM pump for the potassium loop. Delivery was promised the first week in April.

#### Status of Data Reduction and Evaluation

##### Liquid Data

Reduction of the liquid data was completed during this quarter. The liquid test results encompass the following range of parameters:

Reynolds number, $N_{\text{Re}}$	19,000 to 84,000
Peclet number, $N_{\text{Pe}}$	80 to 351
Prandtl number, $N_{\text{Pr}}$	0.004 to 0.0044
Temperature, $T_K$ , $^{\circ}\text{F}$	700 to 810

As discussed in Reference 3, all data reduction was carried out without any relative thermocouple corrections.

The initial correlation of the data weighted all points equally. It was found that 92% of the data could be correlated within  $\pm 15\%$  by the single relation:

$$N_{Nu} = 0.3 + 0.53 N_{Pe}^{0.4} \quad (1)$$

However, a distinction in relative accuracy must be made when considering the results for potassium Peclet numbers greater and less than 120. At values less than 120, the difference between the measured sodium and potassium fluid temperatures at the outlet of the test section varied between  $0.8^{\circ}\text{F}$  and  $2.0^{\circ}\text{F}$ , the minimum difference for the runs at Peclet numbers greater than 120 was  $4.5^{\circ}\text{F}$ .

Since, as cited previously, comparative standardizations of the potassium fluid and wall thermocouples indicated a systematic error of  $1.3^{\circ}\text{F}$  with estimated sodium fluid thermocouple corrections in the same range, the results for the runs at potassium Peclet numbers less than 120 must be considered less accurate than those at values greater than 120. Calculations indicate that a correction of less than  $0.8^{\circ}\text{F}$  in the temperature difference between the sodium and potassium at the test section outlet brings the results for  $N_{Pe} < 120$  into agreement with the measured Nusselt numbers for  $150 < N_{Pe} < 200$ , with increases of less than 12% in the results at higher Peclet numbers.

After qualifying the Nusselt numbers for  $N_{Pe} < 120$ , the initial correlation of Equation 1 has been modified to set the minimum Nusselt number at 3.66 which is equal to the theoretical value that is obtained assuming laminar flow with a constant wall temperature and a parabolic velocity profile (Reference 14). The suggested correlation is:

$$N_{Nu} = 3.66 + 0.0055 (N_{Pe}) \quad (2)$$

The data are compared in Figure 23 to the correlation of Equation 2 and to that of Seban and Shimazaki (Reference 14), and Lubarsky and Kaufman (Reference 15).

#### Condensing Results

The initial reduction of the condensing data was completed during this quarter. The test variables are:

Potassium flow rate, lbs/sec	0.00295 to 0.00334
Sodium flow rate, lbs/sec	0.88 to 1.26
Potassium condenser inlet temp., °F	1167 to 1258
Potassium condenser inlet pressure, psia	3.66 to 6.58
Potassium condensing heat transfer coefficient, Btu/hr-ft <sup>2</sup> , °F	4,000 to 9,000
Condensing heat flux, Btu/hr-ft <sup>2</sup>	1.25 to 2.4 (10 <sup>4</sup> )
Quality range, %	30 to 65
L/D range	19 to 38

Nusselt condensing ratio, $\frac{h}{k} \left( \frac{\nu^2}{g} \right)^{1/3}$	0.011 to 0.023
Film Reynolds number, $\frac{4\pi}{\eta}$	220 to 540
Net Boiler Power, KW	2.7 to 3.1

The reductions were carried out with and without temperature corrections to evaluate the effect of the corrections. Little or no effect of the heat transfer results was obtained at the first axial station, but approximately a 30% increase of the condensing heat transfer coefficient was obtained at the second axial position after a correction was applied to the indicated temperatures. These large errors at the second axial station could have been due to the sodium leakage through a wall thermocouple slot near the bottom of the test section. A plot of condensing heat transfer coefficient as a function of potassium inlet temperature which was obtained from the data reported in Reference 3, is shown in Figure 24-a. As can be seen from Figure 58 of Reference 3, the heat transfer results are lower than Nusselt's condensing theory would predict. Refinements are being considered in an attempt to bring the results into agreement with Nusselt's condensing theory. They are:

1. Obtain a corrected potassium vapor temperature on which to base the condensing heat transfer coefficient allowing for differences in the static and total temperature of the entering vapor.

2. Evaluate the significance of the temperature "jump" at the liquid-vapor interface due to non-equilibrium mass transfer.

Both of these corrections are currently being considered with initial conclusions that:

1. The condensing heat transfer coefficient will be increased by about 30% based on the static rather than total potassium vapor temperature.
- .2. The significance of the temperature "jump" at the interface evaluated in a manner similar to that of Misra, Balabhadra and Bonilla (Reference 16) appears insignificant for the low heat flux runs.

The condensing pressure drop data are presented graphically in Figure 24-b. Measurement of these low pressure drop values was possible by use of the inlet and outlet temperatures as discussed in Reference 3. A Martinelli multiplier of approximately 1000 is indicated. Interpretation of these data will await further measurements to validate the use of these thermocouples as pressure measuring instruments.

#### Revised Test Plan

With the installation of the new boiler, repaired test section, and potassium loop pump, testing will resume at 1150 - 1250°F at intermediate power levels. If the initial trends of the condensing heat transfer

coefficients indicated by the first set of low power runs can be repeated at higher power levels, they may greatly aid in the understanding of alkali metal condensation. The interesting trend of condensing heat transfer coefficients with temperature level need to be validated at higher power levels which will yield correspondingly higher vapor velocities.

A suggested test plan is given below:

<u>Temperature</u> (°F)	<u>(Boiler Power Net)</u> (KW)	<u>Sodium Flow/rate</u> (lb/sec)
1150	10	1.39
	15	1.39
	20	1.39
	25	1.39
1200	10	1.39
	15	1.39
	20	1.39
	25	1.39
1250	10	1.39
	15	1.39
	20	1.39
	25	1.39

After testing has been completed at low temperature, a similar series of runs will be made at 1400 - 1500°F to validate the conclusions drawn from the 1150 - 1250°F data.

Upon completion of this series of test, high power runs will be made up to 50 KW net boiler power at both temperature levels. The high power runs will only be made after the initial series of tests outlined above have been performed in order to minimize the chance of a boiler heater and test

section failure before any data have been obtained. Preceding the condensing runs will be one sodium thermocouple standardization at 1000°F, and a potassium and wall thermocouple standardization at 1200°F. The standardization runs should require no more than 24 hours of loop operation time and are thought to be absolutely necessary for realization of a  $\pm 30\%$  error band in the condensing heat transfer coefficients.

## V. POOL BOILING HEAT TRANSFER INVESTIGATION

### Introduction

Information on pool boiling can be of considerable value in advancing the basic understanding of boiling heat transfer. This phase of the heat transfer program has included a determination of pool boiling heat transfer coefficients for potassium and indications of burn-out heat flux. This phase of the program is under the supervision of Professor C.F. Bonilla and is carried out at Columbia University. The effort during the current quarterly period was directed toward the determination of the overall heat losses for the pool boiler. A description of the pool boiler is given in Reference 17.

### Overall Heat Loss Analysis for the Pool Boiler

#### Procedure

During a boiling run, heat losses from the pool boiling apparatus to the room which occur without passing first into the liquid metal must be subtracted from the electrical input to the heater, to obtain the net heat into the liquid metal. Heat losses from the vapor phase through the walls of the boiling chamber have no bearing on the boiling, though they would be a correction on a boiling heat balance employing the condenser heat load. Heat loss from the liquid phase through the walls of the boiling chamber tend to sub-cool the liquid, yielding "sub-cooled boiling", but would be "overridden" by rising vapor condensing in the liquid phase above the boiling surface at all but the lowest boiling heat fluxes, thus again only amounting to a decrease in condenser load, and not being of concern in the boiling phenomenon or in the heat loss correction. From the boiler

design, it is evident that most of such losses will flow by radiation from the bottom of the molybdenum heater, through the radiation shields, to the bottom half of the outer shell, thence through the thermal insulation to the ambient. Accordingly, such heat losses could be plotted and employed as a function of the temperature of the molybdenum heater element. Since there are no temperature-measuring devices on the heater, the resistance of the heater, obtained by dividing the heater voltage by the current, may be used, provided the resistance is a suitable function of the heater temperature.

The first objective of the calibration runs is thus to determine the heat losses which would not first pass into the liquid metal, if there were metal boiling in the apparatus, as a function of heater temperature. A second objective is to determine whether heater resistance is a suitable indicator of heater temperature, and if so, to plot the heat losses vs. heater temperature for the boiling runs. A third objective of the calibration runs is to serve as a calibration of the plate thermocouples.

The heat losses from the bottom of the heater can best be determined in heat loss runs in which there is no boiling, by subtracting the estimated heat losses from the top and edge of the plate in these runs from the total electrical input. All of these heat rates may for convenience be divided by the area of the boiling plate,  $A$ , so that the correction is directly in the form of a heat flux loss from the bottom,  $(q/A)_{\text{bott}}$ . Thus,

$$(q/A)_{\text{bott}} = (q/A)_{\text{elect}} - (q/A)_{\text{top}} \quad (1)$$

The heat flux loss above the plate can be calculated by measuring the average temperature difference between the (outside) surface of the boiling chamber and the outer surface of the insulation, knowing the conductivity, thickness and surface area of the insulation. Then:

$$(q/A)_{\text{bott}} = (q/A)_{\text{elect}} - \frac{\sum_{S} \frac{k_{\text{av}} \Delta T}{X} \Delta S}{A} \quad (2)$$

where  $S$  is the area of the insulation,  $X$  its thickness, and  $k$  its thermal conductivity. Evidently this method requires a knowledge of  $k$ , whether or not it is a substantial function of temperature. Such a function is available for the commercial insulation used (Reference 18).

An alternative method of employing this same concept is to employ the total electrical heat input for determining  $k$ , assuming only that the actual  $k$  is proportional to the relationship that has been published in Reference 18. The corresponding formula is:

$$(q/A)_{\text{bott}} = (q/A)_{\text{elect}} \frac{\sum \frac{k_{\text{av}} \Delta T}{X} \Delta S_{\text{bottom}}}{\sum \frac{k_{\text{av}} \Delta T}{X} \Delta S_{\text{total}}} \quad (3)$$

An additional procedure is to estimate  $(q/A)_{\text{top}}$  for Equation (1) by measuring the temperature gradient up the boiling chamber wall at the edge of the plate in heat loss runs and calculating the heat conducted in that way. Then adding the estimated heat radiated from the plate upwards to the boiling chamber walls and top.

The method of Equation (2) was actually employed herein, as it required the least information and seemed adequately accurate.

The above procedures yield the average boiling heat flux,  $(q/A)_{boiling, av.}$ , on subtracting  $(q/A)_{bott}$  from  $(q/A)_{elect.}$  in a boiling run. An alternate procedure which will be available employs the pairs of thermocouples whose hot junctions are at the same radial position but different depths to compute both  $(q/A)_{boiling}$ ,  $(q/A)_{local}$  and  $\Delta T_{boiling}$ . It will not be known until actual boiling runs are carried out which method will be preferable; the "average" method utilizing Equation (2) should be more reliable, but has the disadvantage of not yielding a true (local) point if the variation of conditions over the boiling surface is substantial.

### Results

These tests were carried out with two carefully applied layers of insulation over the complete outer surface of the apparatus.

The table below gives the observed plate thermocouple temperatures, in °F, as a function of heater electrical input. Figure 25 shows the location of the thermocouples.

Watts Input	Thermocouple Number							
	°F 2	°F 5	°F $\Delta T^{(1)}$	°F 7	°F 10	°F $\Delta T$	°F Average T	
114	290	257	33	317	320	-3	298	
624	887	881	6	1048	1062	-14	970	
1105	1335	1301	34	1529	1535	-6	1425	
1956	1590	1564	26	1790	1811	-21	1689	
2435	1822	1765	57	2088	2048	+20	1876	
	Average Correction +31					-5		

(1) Opposite to heat flow.

It is seen that the agreement within pairs of couples located at a same radial position is not very good. This is primarily due to the poor performance obtained with smaller diameters of sheathed thermocouples used here, rather than to internal temperature differences in the plate. It is believed that the heat flux normal to the boiling surface between the pairs of hot junctions in the non-boiling runs is not substantial. The radiant  $q/A$  from the top of the plate to the walls of the boiling chamber was calculated for each run and the corresponding  $\Delta T$  between the hot junctions was computed. At maximum, this correction amounted to  $1^{\circ}\text{F}$ ; since it seemed negligible, it was not applied.

The table on Page 68 shows that the calibration correction for each pair of couples which is to be used in boiling runs when calculating local  $(q/A)_{\text{boiling}}$  from the observed temperature difference, have no clear trend with temperature, and the average corrections listed seem appropriate to use. They could also be used when calculating the boiling surface temperatures from the two thermocouples and when testing for self-consistency. Agreement between different pairs of thermocouples is seen to be poor; this is evidently due to radial heat flow toward the edges of the heater, where the heat losses are greater. During actual boiling runs, the plate temperature would be expected to be much more uniform, and these radial variations in heat loss runs might not have to be considered. Figure 26 shows a plot of the relative corrections for each pair of thermocouples vs. the average plate temperature.

Figure 27 is a plot of electrical resistance of the sprayed molybdenum heater vs. the average of the observed temperatures of all of the plate thermocouples. This plot is only qualitative, but does show the substantial and reproducible trend of resistance with temperature, justifying the use of resistance for correlation of the heat losses. The line shows the slope for dense molybdenum (Reference 19).

Figure 28 gives the heat flux loss as a function of heater resistance.

## VI. FACILITIES

### 300 KW Loop

Facility activity on the 300 KW loop during this report period included removal and examination of the 1-inch diameter L-605 single tube test boiler which failed at the end of the last quarter; assembly and installation of a new test boiler; general maintenance, cleaning and inspection of loop components and instrumentation; addition of diffusion type cold traps to the sodium and potassium systems; and circulation of hot liquid metal in both loops for cleaning purposes.

Radiographs taken of the 1-inch diameter test boiler, following its removal from the loop, indicated that a convolution of the bellows provided to accommodate the differential thermal expansion between the boiler tube and boiler shell had failed. The radiographs also showed some evidence of fouling on the outside of the boiler tube. The boiler was disassembled and cleaned with steam and water.

Visual inspection verified the bellows failure as indicated by the radiographs and disclosed a fairly uniform deposit of from 0.005-inch to 0.007-inch thick remaining on the outside of the boiler tube. Analysis of this deposit disclosed a high concentration of Columbium (>10%) indicating that columbium from the sodium hot trap which was removed in November, 1962 was still in the loop.

Reassembly of the 1-inch diameter L-605 single tube boiler with a new tube and rebuilt bellows included the following modifications.

1. The L-605 bellows material was heat treated at 2150<sup>o</sup>F before shipment to the bellows vendor for assembly.
2. The thermal shields provided at the sodium inlet and outlet were eliminated. These shields were originally provided to protect the braze joint between the L-605 and the original molybdenum tube. Removal of these shields will extend the effective heat transfer length of the boiler tube.
3. The 2-inch pitch helical insert was modified to provide additional support for the 1/4-inch O.D. center body tube at the boiling potassium tube exit. This was accomplished by replacing the 1/2-inch O.D. tube of 0.049-inch wall thickness which supported the 1/4-inch O.D. center body with a 1.125-inch O.D. tube of 0.187-inch wall thickness. This tube was welded into the top cap of the boiler. Additional support was obtained by extending the helical ribbon in length so that it covered the entire length of the center body tube and provided restraint in lateral movement. The modified insert also included 7 sheathed thermocouples with junctions spaced along the active heat transfer length.
4. Since difficulty was encountered in obtaining a helium mass spectrometer leak tight braze seal at the thermocouple junction

to the 1/4-inch tube, an argon supply was added to provide an inert atmosphere inside the tube.

5. An independently controlled heater and associated thermocouples were added to the boiler shell area which houses the L-605 bellows to provide heat to the bellows in order to minimize operation at temperatures in the range of 1200<sup>o</sup>F to 1600<sup>o</sup>F, which tend to embrittle the bellows.

During this report period, the following loop maintenance and modifications were accomplished.

1. Both the sodium and potassium pump ducts were removed from the system, cleaned and inspected by radiography.
2. The sodium gas fired heater was visually inspected. New tube wall thermocouples were installed and minor repairs were made to the gas burner.
3. The potassium head tank was opened and inspection. The Cb-1Zr gettering assembly was removed and the tank cleaned and reinstalled.
4. Diffusion type cold traps were added to the sodium and potassium systems.
5. The air heater was removed from the condenser air supply system and the air header was modified to increase air flows to the

horizontal and vertical potassium condensers. Air flow measurements indicate that 4.5 lb/sec of air is now available for condenser cooling. This modification is designed to increase the condenser capacity of the loop so that the full 300 KW design heat transfer capability can be utilized.

6. Loop preheaters, thermocouples and pressure sensors were checked and replaced or repaired as necessary.
7. Following installation of the test boiler hot liquid metal flushing of both loops was initiated to remove residual NaK remaining in the loops from the previous test due to the interchange of fluids resulting from the bellows failure. During the course of this hot flushing erratic flows were observed indicating that some contamination remained in the loop. If hot flushing operations are not successful in removing this contamination it will be necessary to disassemble the loop and employ chemical cleaning techniques.

All L-605 material required for modification of the 300 KW loop to accommodate the multi-tube test boiler was placed on order and is scheduled for delivery early in May.

Design of a 3/4-inch single tube test boiler incorporating thermocouple penetrations, which simulate the thermocouple penetrations proposed for the multi-tube test boiler, was prepared.

100 KW Loop

Installation of a new 3/4-inch schedule 80 test section including heat treating of welds was completed on December 31, 1963. A complete reinstrumentation of the facility as discussed in Section VII was accomplished and heat loss tests on the boiler and preheater radiation cases were completed in January.

Boiling and liquid calibration runs in accordance with the test plan presented in Section III were started early in February. Test operation has continued during the remainder of the quarter with minor interruptions to perform the following repairs.

1. A small leak occurred at the ion gauge provided for measuring chamber pressure. This leak prevented the vacuum chamber from being evacuated below  $10^{-4}$  torr. The ion gauge was replaced with an available spare gauge and loop startup was initiated.
2. During startup following the above repair a short circuit occurred between the boiler radiant heater elements and the reflector assembly. The short circuit was caused because of binding of the tungsten heater elements. Replacement parts were machined and the heater repaired and replaced in two days.
3. Twice during the quarter, it was necessary to interrupt testing and open the vacuum chamber to repair flowmeter leads.

Loop operation during the quarter is summarized as follows:

Total Operating Time	756 hrs.
Total Boiling Time	254 hrs.
Total Stable Boiling Time	247 hrs.
Liquid Data Runs	97

Total operating time for this loop at the end of the quarter was 3381 hours.

Design of the 100 KW preboiler for increasing the boiling capability of this loop was completed with the exception of final review and approval. Orders have been placed for long lead time material for this modification. Installation of the additional electrical power supply which includes three 25 KVA transformers, three 20 KVA saturable reactors, control cabinet, circuit breaker, and interconnecting conduit and cable was started and is scheduled for completion by the middle of April.

#### 50 KW Loop

A new 60 KW boiler was installed in the loop during January. This boiler consists of twenty-four 5/8-inch O.D. x 20-inch long emersion heaters each rated at 2.5 KW at 230 volts welded into a 12-inch type 316 stainless steel tee. Three additional 10 KW variable transformers were installed to supply the electrical power required by this boiler.

Construction of a new test section began immediately following the test section failure on December 7, 1963. A new method of manufacture of the thick walled nickel thermocouple holes, which utilizes brazing rather than

welding techniques, was attempted in an effort to eliminate failures caused by leakage of sodium through the seal welds of the sheet inserts in the tube slots. The old test section was reworked concurrently as a backup. Problems developed in obtaining a helium mass spectrometer leak tight braze with the new test section. The old test section was successfully repaired and was installed in the loop. The principal drawback in using the old test section is that it has only three thermocouples in the top and bottom radial rings as opposed to provisions for five thermocouples in the original test section. Efforts are continuing to complete the new test section. Fabrication of this unit is further discussed in Section VIII.

Repair of the potassium loop MSA conduction type pump is impractical, therefore, a new helical induction type pump was ordered for this loop. Since delivery of the new pump is scheduled for June an attempt was made to operate the potassium loop as a natural circulation loop. Instabilities occurred with this mode of operation which reduced the quality of condensing heat transfer data obtained. A conduction type pump was obtained on loan from G.E. Co. Atomic Power Equipment Department and will be installed early in the next quarter to allow operation of this loop while awaiting delivery of the new pump.

## VII. INSTRUMENTATION

### 300 KW Loop

#### Single Tube Boiler

A reinstrumentation of the 300 KW test boiler was completed as part of the major repair activity accomplished during this reporting period. The boiler shell was instrumented with 55 platinum 10% rhodium - platinum sheathed thermocouples with capped non-grounded junctions arranged in 11 rings of five thermocouples each distributed over the active heat transfer length of the boiler. The axial spacing of the rings was adjusted to maintain a minimum distance between any one ring of thermocouples and the three rings of centering pins used to maintain concentricity between the boiling tube and the shell. Therefore, the axial spacing between the rings is not uniform. Figure 29 is a drawing showing the relative locations of all thermocouples on the boiler. A listing of all thermocouples on the loop test sections including the two condensers is indicated in Table 9.

The method of attachment of the boiler shell thermocouples to the shell surface was by means of 0.003-inch thick foil welded directly to the surface of the boiler shell in such a way that the thermocouple sheath was held in intimate contact for a distance approximately 1.5-inch back from the junction. Figures 30 and 31 are pictures of the boiler shell showing the detailed and the overall method of attachment of the thermocouples. All thermocouple junctions were of the capped non-grounded type. This represents a change in configuration from the last group of thermocouples

used during the December, 1963 loop operation. At that time a majority of the platinum 10% rhodium and platinum wires had been resistance welded directly to the boiler shell in an attempt to measure the outer shell surface temperature more precisely. In the present configuration the junction is located approximately 0.030-inch from the shell surface and is separated from it by a layer of ceramic insulation (alumina) and the sheath (Haynes #25 alloy). The decision to use the capped non-grounded junction configuration was based on the assumption that a reaction between the thermocouple wires and the boiler shell surface might occur at the temperatures normally encountered during boiling operation and that the net result of this reaction could be to change the thermoelectric output characteristic of the thermocouple element. The decision to use capped non-grounded junctions was influenced by the fact that the boiler shell thermocouples are used to mainly to define the slope of the sodium bulk fluid temperature vs. boiler length curve. This slope is not influenced significantly by the location of the junction 0.030-inch from the shell surface providing that all junctions are similar and are attached in the same manner. In practice the provision is difficult to achieve but it is believed that long term stability will be enhanced by the use of capped non-grounded junctions and that errors caused by the location of the junction with respect to the shell surface may be compensated for during liquid-liquid calibration runs.

In addition to the 55 thermocouples located on the shell surface in the 11 rings of five each platinum 10% rhodium - platinum thermocouples were located in each of three rings to provide a check on the error caused by the method

of cold junction compensation. These thermocouples were referenced directly to ice through platinum 10% rhodium, platinum lead wire and are not subject to temperature errors caused by the copper, copper nickel lead wire - CATS block combination. In addition to the six thermocouples located on the boiler shell all of the thermocouples located at the test section inlet and exit thermocouple wells were referenced directly to ice for the reasons described above. The total number of thermocouples referenced directly to ice is 37 including 21 in the test section inlet and exit wells, 6 on the boiler shell, and 10 on the various CATS blocks. This large number necessitated the use of two large vacuum flasks. Some difficulty was experienced in maintaining uniform temperature in the ice baths but this was reduced significantly by the use of individual motorized stirrers with each flask.

A new helical insert was manufactured and installed in the boiler to replace the one which had failed during the December, 1963 loop operation. A drawing of the insert showing manufacturing details and thermocouple locations is shown in Figure 32.

During the shut-down for boiler repairs, the gas fired heater was opened to inspect the thermocouples which had been installed during the manufacture of the heater to measure tube wall temperature. Four of these thermocouples had been installed approximately half way up the boiler tubes and were strapped to the surface of the tube by means of 0.015-inch thick Haynes 25 alloy straps as shown in Figure 33 which is a picture of one of the original

thermocouples which had been in service since the initial start up of the loop. These thermocouples were 0.125-inch O.D. Inco 702 sheathed chromel-alumel with capped non-grounded junctions and were connected to two over-temperature indicators wired into the heater control circuitry so that an induction of a temperature limit as seen by the heater tube wall thermocouples would automatically shut down the heater. Two of the four thermocouples had failed during loop operation and it was decided that replacement was necessary. Access to all tubes in the heater was not possible without major disassembly and therefore it was decided that three tubes which could be worked on through the opening provided in the furnace would be instrumented with several thermocouples each spaced over the length of the tube and attached in the same fashion shown in Figure 33. This will give an indication of temperature gradient along the tube (not available in the previous means of instrumentation which consisted of one thermocouple on each of four tubes).

#### Multi-tube Boiler

A considerable amount of effort has been expended in the design of temperature sensors for the multtube boiler application. Much of this work has been concerned with the problem of getting thermocouples into both the sodium bulk liquid annulus surrounding the tube bundle and into the boiled tubes in such a way that the integrity of the alkali metal containment will not be compromised. The basic method which has been selected for both applications is the use of relatively large diameter, heavy wall tubing with an independent sheathed thermocouple installed after welding of the thermo-

couple well tubing has been completed. This approach makes it possible to replace thermocouples without cutting into the alkali metal system and also provides a secondary containment the details of which are shown in Figure 7. The 0.187-inch O.D. tubing from which the thermocouple wells will be fabricated has a 0.049-inch wall thickness. It is expected that this will provide adequate clearance for a 0.062-inch O.D. sheathed thermocouple. Present plans call for the use of a capped, non-grounded junction configuration for the reasons described above. A platinum 10% rhodium - platinum thermocouple will be used in all thermocouple wells. A source for this wire has been found and preliminary samples have been checked for homogeneity, with excellent results.

Current tube bundle boiler instrument planning provides for two slack diaphragm absolute pressure gages ( $1200^{\circ}\text{F}$  temperature limit), one each at the potassium inlet and outlet of the boiler. In addition, three slack diaphragm pressure difference gages ( $1200^{\circ}\text{F}$  temperature limit) are provided for measurement of the single phase pressure drop across each of the three boiler tube inlet orifices. The reasoning behind the location and selection of these gages is outlined hereafter. It is considered essential to provide some means to determine whether the three boiler tubes are operating equally during operation of the tube bundle boiler, since vapor blanketing and inter-tube or single tube oscillations are possibilities which cannot be completely discounted at this time. Provision has therefore been made to measure relative potassium flow rate in each tube so that regions of instability can be studied and isolated. The individual flow rates will be

determined by measurement of the liquid pressure drop across each of the three inlet orifices by means of pressure difference gages. Preliminary calculations have indicated an orifice pressure drop at 6 psi at the design flow rate. Measurement of the pressure drop through each orifice plate with one common absolute pressure gage sensing inlet pressure and one absolute pressure gage in each tube immediately downstream of the orifice plate would provide a significant cost saving over the installation of 3 differential pressure gages across each orifice plate. The accuracy rating of both types of gages is approximately  $\pm$  1% of full scale range. The full scale range for the absolute gage is the maximum loop operating pressure or nominally 100 psi. The full scale range for the differential pressure gage could be set at 15 psi. Therefore, the error in pressure drop measurement with the two absolute pressure gages could amount to 25% of the maximum orifice pressure drop. The accuracy for the same measurement using three individual differential pressure measurement gages would be approximately 2% of maximum orifice pressure drop. It is felt that the accuracy capability of the two absolute pressure gages is not sufficient and therefore that the extra cost of the differential pressure gages is warranted if the differential pressure gages operate as per specification which has never been proved by experiments with liquid metal applications.

Present plans call for the use of the differential pressure gages to determine stability characteristics of the multitube boiler. It is felt that once stability problems have been solved it will be possible to use the differential pressure measuring sensors to measure the pressure drop

through the individual tubes in the boiling region. This would be from the downstream side of the orifice to the exit of the 3/4-inch tubes.

It is proposed that an absolute pressure gage be installed at the common inlet to the three boiling tubes in order to measure the entering potassium saturation pressure. Another absolute pressure gage installed at the exit of the three boiling tubes is proposed in order to measure the total pressure drop across the tubes and the orifices. This has been calculated to be approximately 15 psi and therefore the accuracy of the differential pressure across the orifice-tube combination could be determined by subtracting the exit absolute pressure from the inlet absolute pressure to an accuracy of approximately 10% of the total pressure drop (15 psi).

The use of high temperature slack diaphragm pressure transducers have been recommended rather than the stressed diaphragm type. A discussion of the basic differences between the two types of pressure transducers has been presented in detail in previous quarterly reports but will be repeated here briefly. The slack diaphragm pressure measuring system uses an incompressible fluid to transmit the pressure forces exerted upon the diaphragm by the high temperature alkali metal to a bourdon tube spring located in a low temperature environment. The major advantage of this construction is that the diaphragm may be made from almost any material since it does not need to have good high temperature spring characteristics. A differential pressure measurement system of the slack and diaphragm type consists of two separate diaphragm-housing units mounted directly on the loop pipe.

The back-loading fluid from each hot diaphragm chamber is directed to a common chamber located in a low temperature environment via capillary tubing. It is necessary to operate both diaphragm housings at the same temperature ( $1200^{\circ}\text{F}$  max) to achieve 1% accuracy capability.

The stressed diaphragm system consists of a diaphragm which is in contact with the hot alkali metal and which must restrain the pressure forces exerted upon it. Displacement of the diaphragm is measured by means of a linear variable differential transformer. Since the diaphragm also serves as a spring in this configuration it is necessary to use a material which has good high temperature spring characteristics. This limits the number of available materials to a relatively small number. The major advantage of this design is the high frequency response which can be obtained. Long term stability is relatively poor due to the fact that the diaphragm is operated at a high stress, high temperature condition and has a tendency to creep. A differential version of the stressed diaphragm pressure transducer is achieved by providing a means for the lower pressure fluid to be in contact with the rear side of the diaphragm. Therefore, the sensing part of the system consists of only a single housing connected to the points of measurement on the loop piping system by means of relatively long connecting tubes. Although the frequency response at the basic transducer itself is high, some response is lost due to the interconnecting tubing, especially if it contains a two phase fluid.

A comparison of the relative merits of the two types of pressure transducers

(slack and stressed diaphragm) is listed in tabular form in Table 10. In considering the problems of differential pressure measurement in general, it becomes apparent that the long term stability is an extremely important parameter because it is usually not possible to perform an in place calibration. Experience had indicated that a slack diaphragm type of transducer is inherently more stable than stressed diaphragm type as indicated in Item 5 of Table 10. The most severe limitation of the slack diaphragm unit is low frequency response. However, the frequency response advantage of the stressed diaphragm transducer is reduced by the relatively long connecting lines (and the possibility of pockets of compressible fluid in these lines) necessary in most practical applications.

#### 100 KW Loop Support

Additional thermocouple feed-through penetrations were provided. The thermocouple alloy material was changed from tungsten - tungsten 26% rhenium to tungsten 3% rhenium - tungsten 26% rhenium. The method of attachment of all thermocouples has been described in Reference 8 and the exact location of all thermocouples in the present 100 KW configuration is shown in Tables C1 and C2.

The decision to switch to the tungsten 3% rhenium alloy in place of the pure tungsten wire was based on a comparison of available metallurgical data and on the basis of an in-loop comparison of tungsten, tungsten 3% rhenium and tungsten 5% rhenium. The tungsten 3% rhenium wire seemed more reliable because it maintained ductility over longer periods at elevated

temperatures. However, there was no established calibration for this wire. It was possible to purchase a tungsten 3% rhenium-tungsten 26% rhenium thermocouple but the mechanical properties of the wire could not be precisely controlled since it would not be possible to run the calibrated wires through any annealing process without possible shift in the calibration. Therefore, it was decided to buy uncalibrated wire and to perform in-house calibration to determine the thermoelectric characteristic for the wire and to also set up a means of checking the homogeneity of the wire in alloy constituents along the length of the wire or for different batches of wire. The homogeneity test procedure of the refractory alloy thermocouple wires has not been set up at this time. However, the procedure for calibration of the thermoelectric output of the tungsten 3% rhenium - tungsten 26% rhenium thermocouple has been completed in an argon atmosphere. Procedures are now being established to allow the same calibration to be performed under a high vacuum environment which is equivalent to the actual operating situation in the 100 KW Facility.

The establishment of an electromotive force vs. temperature characteristic curve for the tungsten 3% rhenium - tungsten 26% rhenium thermocouples used in the 100 KW Facility was accomplished by comparing the thermoelectric EMF of two tungsten 3% rhenium-tungsten 26% rhenium thermocouples with a standard platinum 10% rhodium-platinum thermocouple in an inert gas (argon) atmosphere over the temperature range between 75°F and 2200°F. All three thermocouple junctions were located in a Haynes 25 alloy chamber made from 1-inch diameter tubing. An inner heat shield of 5/8-inch diameter Haynes 25

tubing with a 0.125-inch thick wall served to reduce the temperature gradients along the thermocouple wire. The tungsten 3% rhenium - tungsten 26% rhenium thermocouples were made from 0.005-inch diameter wire. The wires come from the same batch that was used to instrument the 100 KW Facility. The platinum 10% - rhodium - platinum thermocouple was made from 0.020-inch diameter wire which had been calibrated at the freezing points of copper, silver, and antimony. All thermocouples entered the end of the Haynes 25 chamber by means of a compression type fitting utilizing a teflon plug under mechanical pressure to provide a leak tight seal. The thermocouple wires were run in a continuous length directly into an ice reference junction and then through copper wire to a 0.02% accuracy digital recording device. The chamber assembly containing the three thermocouples was inserted approximately 8-inches into the heated zone of a tube furnace. The thermocouple chamber was evacuated and back filled with argon several times before starting any calibration. During the entire calibration an argon pressure of approximately 2 psi was maintained at all times within the chamber.

The calibration was performed by reading the three thermocouples sequentially on the digital recorder at the rate of three readings per second. Several attempts to perform this calibration during relatively rapid transient conditions proved to be unsuccessful and it was found necessary to achieve temperature stabilization at numerous temperature levels in order to obtain valid data. This necessity was due to the fact that all three thermocouples were independent of each other and had different heat absorption and rejection characteristics. The possibility of maintaining a

mechanical contact between all three thermocouple beads during the calibration was rejected on the basis of possible diffusion between the various elements. It was possible to obtain repeatable data by taking readings on the cooling part of the cycle with the power turned off. A large number of data points were taken in this fashion to define the actual slope of the characteristic curve. The absolute level of the characteristic curve was then adjusted to the points at which absolute temperature stabilization had been obtained. This process was necessary due to the large amount of time required to achieve temperature stabilization. A calibration curve was plotted on an expanded scale from the data as described previously and a number of points were extracted from this curve to be used as the basis of a linear interpolation performed on a computer to achieve a working table of temperature vs. millivolts output in  $1^{\circ}\text{F}$  increments. Careful analysis of the data indicates that the average difference between the two tungsten 3% rhenium - tungsten 26% rhenium thermocouples was approximately  $3^{\circ}\text{F}$  at the  $2150^{\circ}\text{F}$  level and proportionately less at lower temperatures. A consideration of all other factors indicates that a  $\pm 0.75\%$  absolute accuracy for the curve as defined above can be justified. However, more work is required to define the degree of homogeneity of the wire. A tabular listing of the values used to compute the temperature - millivolts characteristic curve in  $1^{\circ}\text{F}$  increments is included in Table 11. It must be realized that this calibration is valid only for tungsten 3% rhenium wire manufactured by General Electric Company and tungsten 26% rhenium wire manufactured by the Hoskins Manufacturing Company. The effect of wire drawing, finishing and annealing processes on the thermoelectric characteristic curve is not well defined. Initial efforts

to obtain wire in a stabilized anneal were not successful due to the embrittlement in the wire which occurred during the annealing process. However, further work is being done in the area of defining the effect of annealing on the thermoelectric properties of the wires.

A second calibration on a separate batch of tungsten 3% rhenium vs. the same batch of tungsten 26% rhenium indicated a characteristic curve which was within 0.5% of the initial calibration curve. The second batch of wire was purchased to the same specification but was from a different batch and therefore might be different in calibration.

#### 50 KW Loop

Instrumentation of the repaired test section was completed. Specifications were prepared for an additional set of replacement thermocouples for the test section including inlet and exit wells and nickel tube slots. These thermocouples will be made in a continuous length of sheathed wire from the capped grounded hot junction to the ice reference cold junction.

## VIII. MATERIALS SUPPORT

### 300 KW Loop

#### Single Tube Test Section

A failure occurred in the L-605 alloy bellows between the primary and secondary liquid metal systems. A contributing factor to this failure may have been aging embrittlement which is known to occur in L-605 alloy. Since this bellows was needed to furnish material for fabrication of reconditioned bellows by the vendor, the extent of embrittlement could not be determined. Before shipment to the bellows vendor, all failed L-605 alloy bellows were heat-treated at 2150°F. The L-605 alloy, 1.0-inch diameter tube, was bent because of distortion of the test section, but remained leak-tight.

Another failure occurred in the swirl device inserted inside the 1.0-inch OD tube of the test section. Both the 0.25-inch diameter tube and the 0.50-inch diameter upper support tube failed. The potassium leaked into the tube containing the thermocouples but no significant leakage of potassium to air occurred since the thermocouples were individually brazed into a plug at the top of the swirl device. The failures were both attributed to fatigue. The smaller tube apparently failed first. After failure, deformation of the 0.25-inch tube occurred in the section which remained attached to the 0.50-inch diameter upper support tube. Apparently, violent movement of the broken segment caused the rounded condition illustrated in Figure 34. The cross-section of the area, Figure 35, shows the transition weld intact and the severe mechanical deformation of the tube wall.

To prevent recurrence of this type of failures, the helical swirl insert was redesigned as described in section VII of this report. Essentially, this involved an increase in the diameter of the upper support tube and a decrease in the unsupported length of the 0.25-inch diameter tube.

The 300 KW test section was reassembled and installed in accordance with accepted welding procedures. The L-605 alloy tube (Reference 3) designated #1 which was used in the previous test section was not re-used because it was bent during service. Instead, the nominal 1.0-inch outside diameter with a 0.039-inch wall L-605 alloy tube designated #2 was used. Using this tube required removal of one circumferential defect at a distance of 43.25 inches from the upper end. The tube was rewelded at this position. This weld was polished on the inside and outside diameters to insure negligible flow restriction.

Other modifications in the test section fabrication included removal of the upper and lower thermal shields and installation of a new section of 2.375-inch OD, 0.154-inch wall, L-605 alloy pipe. The modifications are described in section VI.

#### Evaluation of Mo-0.5Ti Alloy Tube

Dimensional, metallographic and chemical analyses as well as bend tests have been performed on the 1.12-inch OD x 0.915-inch ID x 6-foot long Mo-0.5Ti alloy boiler tube which was removed from the 300 KW system several months ago. The inside of the tube was exposed to boiling potassium and

the outside to sodium in the heater circuit for twenty-five hours at 1850°F and one hundred hours at temperatures in excess of 1500°F since the last inspection.

Following removal from the test facility and cleaning to remove residual alkali metal, the boiler tube outside diameter was checked in thirty locations in the same manner described in Reference 9. The outside diameter of the tube was found to have increased an average of approximately one mil in the upper (hotter) portions of the boiler and approximately 0.5 mil at the lower (cooler) end.

Metallographic examination of both longitudinal and transverse specimens of the boiler tube revealed a two-phase metallic deposit on the outside surface of the tube. These surface layers are shown in Figure 36. The thickness of the layers on the specimens taken from the lower regions of the boiler tube was slightly less (approximately 0.5 mil) than those observed on the specimens from the upper regions. The brittle nature of the deposit was evidenced by numerous radial cracks. Only a minor amount of recrystallization of the Mo-0.5Ti tube was apparent. No surface layers or corrosion was observed on the inner surface (potassium side) of the boiler tube.

Spectrographic analysis was performed on specimens taken from the upper regions of the boiler tube. These results, summarized in Table 12, confirm the transfer of L-605 alloy elements to the surface of the Mo-0.5Ti

boiler tube. Specimens are currently being prepared for electron beam microprobe analysis. The concentration gradient of the various elements in the surface layers and in the molybdenum alloy substrate will be determined by these analyses.

Bend tests on longitudinal specimens (0.5-inch wide x 1.5-inch long x 0.085-inch thick) cut from the top region of the boiler tube have been conducted at a series of temperatures to determine the bend transition temperature of the molybdenum tube. It was thought that the brittle surface layer discussed above might have caused a significant increase in the transition temperature. The test specimens were bent 100° over a 0.31-inch radius (bend ratio  $\sim$  3.7) with the bend axis in the transverse direction. As shown in Figure 37, the specimens were ductile at 400°, 300° and 200°F. Two specimens were bent at 100°F, one specimen as cut from the tube, and one specimen with the surface layer described above polished away. These low-temperature specimens bent in a ductile fashion; however, some cracking resulted from the restraint introduced by the bending die. It may be concluded from the results obtained that the brittle layer described above had no marked effect on the ductility of the Mo-0.5Ti alloy.

#### Multi-Tube Boiler

Material support activities included procurement of L-605 alloy, for trial tube forming operations, and review of weld joint design.

All the L-605 cobalt base alloy was ordered to the following specification; SPPS-4A"Forgings",SPPS-5A"Tube and Pipe",and SPPS-6A"Sheet, Strip and Plate." Also, a system of material control numbers has been established to insure proper identification and quality assurance of all incoming materials.

Tube forming to the multi-tube test boiler configuration has been initiated. To provide forming conditions that are more severe than required for the multi-tube boiler (0.75-inch diameter tubes), a 1.0-inch outside diameter L-605 alloy tube was supplied to the forming vendor. Upon completion of the forming operation the tubing will be inspected for defects and examined for uniformity of wall reduction.

#### 100 KW Loop Support

##### Loop Modification

The modification of the 100 KW loop for increased power input has proceeded with the placement of orders for required Cb-1Zr alloy, the inspection and commitment of the Cb-1Zr alloy tubing required for forming of the work-horse boiler, design and machining of the required bimetallic joint between Cb-1Zr and Type 316 stainless steel pipe, and completion of qualification of field welding procedures for 0.75-inch schedule 80 Cb-1Zr pipe in the horizontal position (weld vertical).

For qualification of the field welding procedures, trial welds were made utilizing standard inert gas shielding techniques. An envelope of helium gas was provided by two "shower heads" placed on each side of the joint,

helium purging of the pipes being joined, and the helium torch gas.

Chemical analyses of the weld metal indicated an acceptable degree of gaseous contamination as shown in Table 13.

Evaluation of Cb-1Zr Containment Alloy

A section of 0.75-inch Schedule 80 Cb-1Zr alloy pipe located directly above the mixer was removed from the 100 KW loop in December, 1963. This pipe had been in the loop for the entire life of the loop and had been subjected to the following thermal exposure:

Above 800°F	-	2,625 hours
Above 1500°F	-	668 hours
Maximum Temperature	-	2100°F

Approximately two-thirds (Reference 9) of the total exposure was with sodium in the system, the change to potassium operation began in June, 1963.

Metallographic examinations, hardness surveys, and chemical analyses were carried out on this component in order to make a reasonable estimate of the metallurgical condition of the hotter loop components which have not been replaced, i.e., condenser and vapor lines.

The appearance of the polished cross sections of the pipe following removal from the loop is shown in Figure 38. Detailed examination at high magnification (1000X) revealed a band of  $ZrO_2$  precipitation extending from the inside surface to a depth of 0.024-inch into the pipe wall. Photomicrographs taken in the contamination zone and in the essentially uncontaminated region are shown in Figure 39. The area shown in (b) is typical of all

regions of the pipe wall outside the dark band. The results of the hardness survey across the pipe wall are given in Table 14. Hardness values in the "contaminated" zone were 20 to 50 DPH numbers higher than in the "uncontaminated" zone.

Chemical analyses were conducted on machined sections of the pipe wall in order to determine the concentration gradient of interstitial elements. The pipe section was machined into three 0.050-inch thick ring segments representing the outer, center, and inside thirds of the tube wall. The results of the chemical analyses are given in Table 15. These results indicate substantial contamination of the inner surface of the pipe with oxygen. The outer ring increased in oxygen to the 500 ppm level. It should be noted that the outside diameter of this pipe was wrapped with Cb-1Zr alloy foil for thermal insulation, and this undoubtedly reduced the contamination from the vacuum environment.

The degree of contamination noted both chemically and metallographically indicates that the loop should provide a suitably long life for continued operation with potassium at temperatures up to 2200°F.

#### 50 KW Loop Support

A new nickel test section is being manufactured using brazed techniques to seal the thermocouple slots and to produce the joints between the nickel test section and the Type 316 stainless steel inlet and outlet pipes. The brazing alloy selected was Coast Metal 52 Special (20Co-4.50Si-3.30B-Bal. Ni) which had been used successfully on the previous test section.

To prevent the brazing alloy from flowing into the thermocouple passages, stainless steel tubes were placed in the bottom of each groove in the test section before the nickel sheet was inserted, filling the remainder of the groove. The test section was brazed using two cycles at 1950°F in vacuum.

Post-braze inspection indicated several areas of incomplete brazing alloy penetration which caused leakage along the thermocouple wells. This test section is scheduled for repair brazing early in the next quarter.

To avoid undue delay in program schedule, the original nickel test section was repair-welded. This test section was assembled and installed in the 50 KW loop following accepted welding procedures.

REFERENCES

1. Dwyer, O.E., "Wall and Bulk Temperatures for Fluids Flowing in Concentric Annuli", BNL Report 6177, May 28, 1962.
2. Gunter, A.Y. and Shaw, W.A., "A General Correlation of Friction Factors for Various Types of Surfaces in Crossflow", Trans. of ASME, Volume 67, No. 8, November, 1945.
3. "Alkali Metal Boiling and Condensing Investigations", Quarterly Report No. 6, Ctr. NAS3-2528, SPPS, MSD, General Electric Company, April 20, 1964.
4. Rourk, R.J., "Formulas for Stress and Strain", McGraw Hill Book Company, 1943.
5. Abraham, L.H., "Structural Design of Missiles and Spacecraft", McGraw Hill Book Company, 1962.
6. "Liquid Metals Handbook, Sodium (NaK) Supplement" Atomic Energy Commission and Department of the Navy, Third Edition, July 1955.
7. "Heat Transfer Design Data", General Electric Company, Section G-507,3, page 2, December, 1961.
8. "Alkali Metal Boiling and Condensing Investigations", Quarterly Reports No. 2 and 3, Ctr. NAS3-2528, SPPS, MSD, General Electric Company, April 20, 1963.
9. "Alkali Metal Boiling and Condensing Investigations", Quarterly Report No. 5, Ctr. NAS3-2528, SPPS, MSD, General Electric Company, January 6, 1964.
10. Weatherford, W.P., et.al., "Properties of Inorganic Energy Conversion Heat Transfer Fluids for Space Applications", Report 61-96, WAPD, November, 1961.
11. Phillips, T.A. and McCarthy, M.E., "Thermodynamic Properties of Potassium Calculated From Experimental Data in the Temperature Range of 1200 to 2700°R", MSD, General Electric Company, Evendale, Ohio, January, 1964.
12. Affel, R.G., et.al, "Calibration and Testing of 2 and 3-1/2 Inch Magnetic Flowmeters for High Temperature NaK Service", Report ORNL-2793, Oak Ridge National Laboratory.
13. "Alkali Metal Boiling and Condensing Investigations", Quarterly Report No. 3, Ctr. NAS5-681, SPPS, MSD, General Electric Company, October 31, 1961.

REFERENCES (Continued)

14. Seban, R.A. and T. Shimazaki, "Heat Transfer to a Fluid Flowing Turbulently in a Smooth Pipe with Walls at a Constant Temperature", Paper No. 50-A-128, ASME, 1950.
15. Lubarsky, B., and Kaufman, S.J., "Review of Experimental Investigations of Liquid-Metal Heat Transfer", NACA TN 3336, 1955.
16. Misra, Balabhadra and Bonilla, C.F., "Heat Transfer in the Condensation of Metal Vapors: Mercury and Sodium up to Atmospheric Pressure", Paper No. 51, Chemical Engineering Progress Symposium Series, No. 18, 1955, Vol. 52.
17. "Alkali Metal Boiling and Condensing Investigations", Quarterly Report No. 4, Ctr. NAS5-681, SPPS, MSD, General Electric Company, October-December, 1961.
18. "Heat Transfer Design Data", General Electric Company, Section G515.1, December, 1961.
19. WADC TR-58-476.

TABLE I

NOMENCLATURE FOR IBM PRINTOUT  
FOR 300 KW MULTI-TUBE BOILER

BOILEN	Boiling tube length, in.
DELP	Total secondary pressure drop, psi.
DTO	Outside tube diameter, in.
DTI	Inside tube diameter, in.
FLUXI	Heat flux based on TKIN = Constant Btu/ $\text{ft}^2\text{hr}$ .
FLUXO	Heat flux based on TKOUT = Constant Btu/ $\text{ft}^2\text{hr}$ .
GK	Mass Velocity, $\text{lb}_m/\text{ft}^2\text{-sec}$ .
HST	Sodium heat transfer coefficient, Btu/ $\text{ft}^2\text{hr-}^\circ\text{F}$ .
HINNP	Potassium heat transfer coefficient, Btu/ $\text{ft}^2\text{hr-}^\circ\text{F}$ .
NT	Number of tubes
PMOM	Momentum pressure drop, psi
POWER	Boiler power level, KW
THICK	Wall Thickness, in.
TPIN	Inlet potassium saturation temperature, $^\circ\text{F}$
TPOUT	Exit potassium saturation temperature, $^\circ\text{F}$
TSIN	Inlet sodium temperature, $^\circ\text{F}$
TSOUT	Exit sodium temperature, $^\circ\text{F}$
TSX	Sodium temperature distribution, $^\circ\text{F}$
UI	Overall heat transfer coefficient distribution, Btu/ $\text{ft}^2\text{hr-}^\circ\text{F}$
WPT	Potassium flow rate per tube, $\text{lb}_m/\text{sec}$ .
WPTOT	Total potassium flow rate, $\text{lb}_m/\text{sec}$ .
WS	Sodium flow rate, $\text{lb}_m/\text{sec}$ .
XL	Axial quality distribution
XOUT	Exit quality
ZLEN	Axial length, in.

Table 2  
BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER TP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
200.00	3	0.7500	0.6740	0.03800		175.87

PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
TSIN= 1850.00 DEG F.  
TSOUT=1807.02 DEG F.

SECONDARY POTASSIUM SIDE

WPT= 0.0768 LB/SEC  
WPTOT= 0.2303 LB/SEC  
TPIN= 1679.97 DEG F.  
TPOUT=1650.00 DEG F.  
XOUT= 1.0000  
DELP= 5.7864 PSIA  
PMJM= 2.1654 PSIA  
GK= 30.987 LBM/SQFT SEC

SODIUM TPOUT ITERATIONS  
2

TPIN ITERATIONS  
10

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1807.02	5000.0	5000.0	1724.8	0.	219128.	270828.
3.50	1809.17	5000.0	5000.0	1724.8	0.0500	222835.	274535.
6.94	1811.32	5000.0	5000.0	1724.8	0.1000	226542.	278242.
10.33	1813.46	5000.0	5000.0	1724.8	0.1500	230249.	281949.
13.66	1815.61	5000.0	5000.0	1724.8	0.2000	233956.	285656.
16.94	1817.76	5000.0	5000.0	1724.8	0.2500	237663.	289363.
20.17	1819.91	5000.0	5000.0	1724.8	0.3000	241369.	293070.
23.35	1822.06	5000.0	5000.0	1724.8	0.3500	245076.	296776.
26.48	1824.21	5000.0	5000.0	1724.8	0.4000	248783.	300483.
29.57	1826.36	5000.0	5000.0	1724.8	0.4500	252490.	304190.
32.61	1828.51	5000.0	5000.0	1724.8	0.5000	256197.	307897.
35.61	1830.66	5000.0	5000.0	1724.8	0.5500	259904.	311604.
38.56	1832.81	5000.0	5000.0	1724.8	0.6000	263611.	315311.
41.48	1834.96	5000.0	5000.0	1724.8	0.6500	267318.	319018.
44.35	1837.11	5000.0	5000.0	1724.8	0.7000	271025.	322725.
49.47	1839.25	5000.0	200.0	185.9	0.7500	29607.	35179.
75.42	1841.40	5000.0	200.0	185.9	0.8000	30007.	35578.
101.03	1843.55	5000.0	200.0	185.9	0.8500	30406.	35978.
126.30	1845.70	5000.0	200.0	185.9	0.9000	30806.	36377.
151.25	1847.85	5000.0	200.0	185.9	0.9500	31205.	36777.
175.87	1850.00	5000.0	200.0	185.9	1.0000	31605.	37176.

Table 2 (Cont'd)

## BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER TP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
220.00	3	0.7500	0.6740	0.03800		206.35

## PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
 TSIN= 1850.00 DEG F.  
 TSOUT=1802.70 DEG F.

## SECONDARY POTASSIUM SIDE

WPT= 0.0845 LB/SEC  
 WPTOT= 0.2534 LB/SEC  
 TPIN= 1688.56 DEG F.  
 TPOUT=1650.00 DEG F.  
 XOUT= 1.0000  
 DELP= 7.5432 PSIA  
 PMOM= 2.5783 PSIA  
 GK= 34.086 LBM/SQFT SEC

SODIUM TPOUT ITERATIONS  
2

TPIN ITERATIONS  
10

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1802.70	5000.0	5000.0	1724.8	0.	196881.	263389.
4.28	1805.07	5000.0	5000.0	1724.8	0.0500	200960.	267468.
8.47	1807.43	5000.0	5000.0	1724.8	0.1000	205039.	271547.
12.58	1809.80	5000.0	5000.0	1724.8	0.1500	209118.	275625.
16.61	1812.16	5000.0	5000.0	1724.8	0.2000	213196.	279704.
20.56	1814.53	5000.0	5000.0	1724.8	0.2500	217275.	283783.
24.44	1816.89	5000.0	5000.0	1724.8	0.3000	221354.	287862.
28.25	1819.26	5000.0	5000.0	1724.8	0.3500	225433.	291941.
31.99	1821.62	5000.0	5000.0	1724.8	0.4000	229512.	296020.
35.66	1823.99	5000.0	5000.0	1724.8	0.4500	233591.	300099.
39.27	1826.35	5000.0	5000.0	1724.8	0.5000	237670.	304177.
42.82	1828.72	5000.0	5000.0	1724.8	0.5500	241748.	308256.
46.31	1831.08	5000.0	5000.0	1724.8	0.6000	245827.	312335.
49.75	1833.45	5000.0	5000.0	1724.8	0.6500	249906.	316414.
53.12	1835.81	5000.0	5000.0	1724.8	0.7000	253985.	320493.
59.12	1838.18	5000.0	200.0	185.9	0.7500	27811.	34978.
89.48	1840.54	5000.0	200.0	185.9	0.8000	28251.	35418.
119.36	1842.91	5000.0	200.0	185.9	0.8500	28690.	35858.
148.79	1845.27	5000.0	200.0	185.9	0.9000	29130.	36297.
177.78	1847.64	5000.0	200.0	185.9	0.9500	29569.	36737.
206.35	1850.00	5000.0	200.0	185.9	1.0000	30009.	37176.

TABLE 2 (Cont'd)  
BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER TP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
240.00	3	0.7500	0.6740	0.03800		244.92

PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
TSIN= 1850.00 DEG F.  
TSOUT=1798.39 DEG F.

SECONDARY POTASSIUM SIDE

WPT= 0.0921 LB/SEC  
WPTOT= 0.2764 LB/SEC  
TPIN= 1699.18 DEG F.  
TPOUT=1650.00 DEG F.  
XOUT= 1.0000  
DELP= 9.7792 PSIA  
PMOM= 3.0089 PSIA  
GK= 37.184 LBM/SQFT SEC

SODIUM TPOUT ITERATIONS

2

TPIN ITERATIONS

8

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1798.39	5000.0	5000.0	1724.8	0.	171122.	255945.
5.35	1800.97	5000.0	5000.0	1724.8	0.0500	175573.	260396.
10.58	1803.55	5000.0	5000.0	1724.8	0.1000	180024.	264847.
15.67	1806.13	5000.0	5000.0	1724.8	0.1500	184475.	269298.
20.64	1808.71	5000.0	5000.0	1724.8	0.2000	188926.	273749.
25.50	1811.29	5000.0	5000.0	1724.8	0.2500	193377.	278200.
30.24	1813.87	5000.0	5000.0	1724.8	0.3000	197829.	282651.
34.88	1816.45	5000.0	5000.0	1724.8	0.3500	202280.	287102.
39.42	1819.03	5000.0	5000.0	1724.8	0.4000	206731.	291553.
43.86	1821.61	5000.0	5000.0	1724.8	0.4500	211182.	296004.
48.21	1824.19	5000.0	5000.0	1724.8	0.5000	215633.	300455.
52.47	1826.77	5000.0	5000.0	1724.8	0.5500	220084.	304906.
56.65	1829.36	5000.0	5000.0	1724.8	0.6000	224535.	309357.
60.74	1831.94	5000.0	5000.0	1724.8	0.6500	228986.	313809.
64.76	1834.52	5000.0	5000.0	1724.8	0.7000	233437.	318260.
71.87	1837.10	5000.0	200.0	185.9	0.7500	25637.	34778.
107.74	1839.68	5000.0	200.0	185.9	0.8000	26116.	35258.
142.95	1842.26	5000.0	200.0	185.9	0.8500	26596.	35737.
177.54	1844.84	5000.0	200.0	185.9	0.9000	27076.	36217.
211.52	1847.42	5000.0	200.0	185.9	0.9500	27555.	36697.
244.92	1850.00	5000.0	200.0	185.9	1.0000	28035.	37176.

Table 3

## BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER GP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
200.00	3	0.7500	0.6740	0.03800		183.08

## PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
 TSIN= 1850.00 DEG F.  
 TSOUT=1807.02 DEG F.

## SECONDARY POTASSIUM SIDE

WPT= 0.0768 LB/SEC  
 WPTOT= 0.2303 LB/SEC  
 TPIN= 1686.18 DEG F.  
 TPOUT=1650.00 DEG F.  
 XOUT= 1.0000  
 DELP= 7.0519 PSIA  
 PMOM= 2.1403 PSIA  
 GK= 30.987 LBM/SQFT SEC

SODIUM TPOUT ITERATIONS  
2TPIN ITERATIONS  
11

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1807.02	5000.0	5000.0	1724.8	0.	208423.	270828.
3.68	1809.17	5000.0	5000.0	1724.8	0.0500	212129.	274535.
7.29	1811.32	5000.0	5000.0	1724.8	0.1000	215836.	278242.
10.85	1813.46	5000.0	5000.0	1724.8	0.1500	219543.	281949.
14.34	1815.61	5000.0	5000.0	1724.8	0.2000	223250.	285656.
17.78	1817.76	5000.0	5000.0	1724.8	0.2500	226957.	289363.
21.16	1819.91	5000.0	5000.0	1724.8	0.3000	230664.	293070.
24.48	1822.06	5000.0	5000.0	1724.8	0.3500	234371.	296776.
27.76	1824.21	5000.0	5000.0	1724.8	0.4000	238078.	300483.
30.98	1826.36	5000.0	5000.0	1724.8	0.4500	241785.	304190.
34.16	1828.51	5000.0	5000.0	1724.8	0.5000	245491.	307897.
37.28	1830.66	5000.0	5000.0	1724.8	0.5500	249198.	311604.
40.36	1832.81	5000.0	5000.0	1724.8	0.6000	252905.	315311.
43.40	1834.96	5000.0	5000.0	1724.8	0.6500	256612.	319018.
46.39	1837.11	5000.0	5000.0	1724.8	0.7000	260319.	322725.
51.72	1839.25	5000.0	200.0	185.9	0.7500	28454.	35179.
78.72	1841.40	5000.0	200.0	185.9	0.8000	28853.	35578.
105.34	1843.55	5000.0	200.0	185.9	0.8500	29253.	35978.
131.60	1845.70	5000.0	200.0	185.9	0.9000	29652.	36377.
157.51	1847.85	5000.0	200.0	185.9	0.9500	30051.	36777.
183.08	1850.00	5000.0	200.0	185.9	1.0000	30451.	37176.

Table 3 (Cont'd)

## BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER GP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
220.00	3	0.7500	0.6740	0.03800		219.03

## PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
 TSIN= 1850.00 DEG F.  
 TSOUT=1802.70 DEG F.

## SECONDARY POTASSIUM SIDE

WPI= 0.0845 LB/SEC  
 WPTOT= 0.2534 LB/SEC  
 TPIN= 1697.10 DEG F.  
 TPOUT=1650.00 DEG F.  
 XOUT= 1.0000  
 DELP= 9.3351 PSIA  
 PMDM= 2.5380 PSIA  
 GK= 34.086 LBM/SQFT SEC

## SODIUM TPOUT ITERATIONS

2

## TPIN ITERATIONS

5

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1802.70	5000.0	5000.0	1724.8	0.	182158.	263389.
4.62	1805.07	5000.0	5000.0	1724.8	0.0500	186237.	267468.
9.14	1807.43	5000.0	5000.0	1724.8	0.1000	190316.	271547.
13.56	1809.80	5000.0	5000.0	1724.8	0.1500	194394.	275625.
17.89	1812.16	5000.0	5000.0	1724.8	0.2000	198473.	279704.
22.14	1814.53	5000.0	5000.0	1724.8	0.2500	202552.	283783.
26.30	1816.89	5000.0	5000.0	1724.8	0.3000	206631.	287862.
30.37	1819.26	5000.0	5000.0	1724.8	0.3500	210710.	291941.
34.37	1821.62	5000.0	5000.0	1724.8	0.4000	214789.	296020.
38.30	1823.99	5000.0	5000.0	1724.8	0.4500	218868.	300099.
42.15	1826.35	5000.0	5000.0	1724.8	0.5000	222946.	304177.
45.93	1828.72	5000.0	5000.0	1724.8	0.5500	227025.	308256.
49.64	1831.08	5000.0	5000.0	1724.8	0.6000	231104.	312335.
53.29	1833.45	5000.0	5000.0	1724.8	0.6500	235183.	316414.
56.88	1835.81	5000.0	5000.0	1724.8	0.7000	239262.	320493.
63.25	1838.18	5000.0	200.0	185.9	0.7500	26224.	34978.
95.42	1840.54	5000.0	200.0	185.9	0.8000	26664.	35418.
127.07	1842.91	5000.0	200.0	185.9	0.8500	27104.	35858.
158.21	1845.27	5000.0	200.0	185.9	0.9000	27543.	36297.
188.86	1847.64	5000.0	200.0	185.9	0.9500	27983.	36737.
219.03	1850.00	5000.0	200.0	185.9	1.0000	28422.	37176.

TABLE 3 (Cont'd)

## BOILER DESIGN POINT

CASE= 300KW MULTITUBE BOILER GP DP 3/5/64

MODE OF OPERATION= COUNTERFLOW ,STR. TUBE

POWER KW	NT	DTO IN.	DTI IN.	THICK IN.	ANNHT IN.	BOILEN IN.
240.00	3	0.7500	0.6740	0.03800		268.85

## PRIMARY SODIUM SIDE

WS= 14.0000 LB/SEC  
 TSIN= 1850.00 DEG F.  
 TSOUT=1798.39 DEG F.

## SECONDARY POTASSIUM SIDE

WPT= 0.0921 LB/SEC  
 WPTOT= 0.2764 LB/SEC  
 TPIN= 1711.19 DEG F.  
 TPOUT=1650.00 DEG F.  
 XOUT= 1.0000  
 DELP= 12.3941 PSIA  
 PMOM= 2.9443 PSIA  
 GK= 37.184 LBM/SQFT SEC

SODIUM TPOUT ITERATIONS  
2

TPIN ITERATIONS  
9

ZLEN IN.	TSX DEG F.	HST HR UNITS	HINNP HR UNITS	UI HR UNITS	XL	FLUXI HR UNITS	FLUXO HR UNITS
0.	1798.39	5000.0	5000.0	1724.8	0.	150410.	255945.
6.08	1800.97	5000.0	5000.0	1724.8	0.0500	154861.	260396.
11.99	1803.55	5000.0	5000.0	1724.8	0.1000	159312.	264847.
17.74	1806.13	5000.0	5000.0	1724.8	0.1500	163763.	269298.
23.33	1808.71	5000.0	5000.0	1724.8	0.2000	168214.	273749.
28.78	1811.29	5000.0	5000.0	1724.8	0.2500	172665.	278200.
34.08	1813.87	5000.0	5000.0	1724.8	0.3000	177116.	282651.
39.26	1816.45	5000.0	5000.0	1724.8	0.3500	181567.	287102.
44.31	1819.03	5000.0	5000.0	1724.8	0.4000	186018.	291553.
49.24	1821.61	5000.0	5000.0	1724.8	0.4500	190469.	296004.
54.06	1824.19	5000.0	5000.0	1724.8	0.5000	194920.	300455.
58.76	1826.77	5000.0	5000.0	1724.8	0.5500	199371.	304906.
63.37	1829.36	5000.0	5000.0	1724.8	0.6000	203822.	309357.
67.87	1831.94	5000.0	5000.0	1724.8	0.6500	208273.	313809.
72.28	1834.52	5000.0	5000.0	1724.8	0.7000	212725.	318260.
80.08	1837.10	5000.0	200.0	185.9	0.7500	23405.	34778.
119.34	1839.68	5000.0	200.0	185.9	0.8000	23884.	35258.
157.81	1842.26	5000.0	200.0	185.9	0.8500	24364.	35737.
195.54	1844.84	5000.0	200.0	185.9	0.9000	24844.	36217.
232.54	1847.42	5000.0	200.0	185.9	0.9500	25323.	36697.
268.85	1850.00	5000.0	200.0	185.9	1.0000	25803.	37176.

TABLE 4

BASIC DESIGN REQUIREMENTS OF THE MULTI-TUBE BOILER

Operating Conditions

Temperature:	1850°F Continuous 2000°F Transient, 50°F/min
Pressure:	80 psi Continuous shell pressure 150 psi Transient shell pressure
Life:	1000 hours - minimum of 50 room to operating temperature cycles.
Primary Fluid:	Sodium Inlet -----1800 - 1850°F Exit -----1750 - 1800°F Flow -----7 - 14 lb/sec Pressure --40 - 65 psi
Secondary Fluid:	Potassium Inlet -----1100 - 1500°F Exit -----1650°F (nominal) Flow -----.24 - .39 lb/sec Pressure --5 - 45 psi

CONFIGURATION

1. The unit diameter and length shall be compatible for installation into the existing 300 KW facility.
2. The boiler shall be sized or mounted such that bending of the boiler shell will not occur.
3. Orientation of the unit shall be such that it is in a vertical operating position.
4. Servicing of the unit shall have the following considerations:
  - a. Provisions for lifting and normal handling.
  - b. Provisions for drainage of liquid metal from all cavities.
  - c. Capability of tube inspection, repair and/or replacement.
  - d. Changes of instrumentation without boiler disassembly.
5. Liquid metal to air wall thickness at any region shall not be less than .030 inches. In addition, for reasons of safety, double containment is preferred in these areas.
6. The unit shall be designed such that basic modifications to the facility will not impede the installation of a superheater at a later date.

MATERIAL AND FABRICATION

1. Shell and tube components shall be constructed from L-605
2. All welds will be full penetration, crevice free.

TABLE 5  
SOME PROPERTIES OF L-605 (HAYNES #25)  
AT ELEVATED TEMPERATURES

	<u>PROPERTY</u>	<u>1600°F</u>	<u>1800°F</u>	<u>1850°F</u>
U <sub>TS</sub> ,	Ultimate Tensile Strength, psi	35,000	22,700	22,000
Y.S.,	Yield Strength ( $\leq$ 1 hr.), psi	25,000	16,000	14,000
R.S.,	Rupture Strength (1000 hr) psi	8,400	2,800	1,900
K,	Thermal Conductivity, $\frac{\text{Btu}\cdot\text{ft}}{\text{Hr}/{}^{\circ}\text{F}\cdot\text{ft}^2}$	15.0	16.0	16.0
E,	Modulus of Elasticity, psi	$24.9 \times 10^6$	$22 \times 10^6$ <sup>a</sup>	$20 \times 10^6$ <sup>a</sup>
$\alpha$ ,	Coefficient of Thermal Expansion In/In- ${}^{\circ}\text{F}$	$9.06 \times 10^{-6}$	$9.41 \times 10^{-6}$	$9.5 \times 10^{-6}$
K & N <sub>a</sub>	Corrosion Rate In/1000 hr			.005 <sup>b</sup>
	Oxidation Rate In/1000 hr			.003 <sup>b</sup>
	Design Stress = $\frac{\text{R.S.}}{2}$ psi	4,200	1,400	950
	Design Stress = $\frac{\text{R.S.}}{3}$ psi	2,700	930	630
$\epsilon$ ,	Thermal Diffusivity ft <sup>2</sup> /sec		$50 \times 10^{-6}$	

a. "Haynes Alloy #25", Haynes Stellite Company, March, 1959.

b. Semmel, J.W., Young, W.R. and Kearns, W.A., "Alkali Metals Boiling and Condensing Investigations, Vol. II Material Support", CTR. NAS5-681-SPPS, MSD, General Electric Co., January, 1963.

**TABLE 6**  
**STRUCTURAL DESIGN SUMMARY**  
 (See Figure 5)

Member	Design Pressure Psi	Design Temp. °F	Temp. Gradient °F	Thermal R.T. to Operating Cycles	Fatigue Cycles	Design Thickness In.	Remarks
A	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.20	All Radii 1/2 in. Min.
B	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.55	" " " "
C	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.70	" " " "
D	80	1850	250	>10 <sup>2</sup>	>10 <sup>2</sup>	1.25	" " " "
E	80	1850	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.70	Full Penetration Weld
F	80	1850	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.25	" " "
G	80	1850	275	275	≥10 <sup>3</sup>	.035	W/1200°F Sec. Inlet
			190	190	≥10 <sup>3</sup>	.035	W/1400°F Sec. Inlet
H	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.60	All Radii 1/2 in. Min.
I	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.40	" " " "
J	50	1800	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.20	" " " "
K	80	1850	250	>10 <sup>2</sup>	>10 <sup>2</sup>	1.10	" " " "
L	80	1850	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.60	" " " "
M	0	1800	100	>10 <sup>3</sup>	>10 <sup>3</sup>	.20	" " " "
N	80	1850	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.060	1 Atm. Argon Internal
P	80	1850	10	>10 <sup>4</sup>	>10 <sup>4</sup>	.10	" " " "
Q	0	1850	50	>10 <sup>3</sup>	>10 <sup>3</sup>	.060	" " " "
R	0	1850	0	>10 <sup>5</sup>	>10 <sup>5</sup>	.050	" " " "

TABLE 7

BASIC DESIGN REQUIREMENT - 300 KW SUPERHEATER TEST UNIT

Operating Conditions

Temperature:	1850°F Continuous 2000°F Transient, 50°F/Min
Pressure:	80 psia Continuous, Shell 150 psia Transient, Shell
Life:	1000 hours - minimum 50 room to operating temperature cycles
Primary Fluid:	Sodium Inlet -----1800 - 1850°F Exit -----1790 - 1840°F Flow -----7 - 14 lb/sec Pressure --40 - 65 psia
Secondary Fluid:	Potassium Inlet -----1600 - 1650°F X = .98 Exit -----1650 - 1700°F X =1.00 50°F Superheat Flow -----.24 - .39 lb/sec Pressure --35 - 55 psia

CONFIGURATION

1. The unit diameter, length and nozzle locations shall be compatible for installation into the 300 KW facility.
2. The unit shall be sized or mounted in such a way that bending of the boiler shell will not occur.
3. For reasons of servicing, the unit shall have the following:
  - a. Provisions for lifting and normal handling.
  - b. Provisions for drainage of liquid metal from major cavities.
4. Liquid metal to air wall thickness at any region shall not be less than .030 inches. In addition, for reasons of safety, double containment is preferred in these areas.

MATERIAL AND FABRICATION

1. Shell and tube components shall be constructed from L-605. These materials will conform to specifications SPPS 4A, 5A, 6A.
2. All welds will be full penetration, crevice free and shall conform to welding specification SPPS 8A.

TABLE 8

100 KW TEST PLAN

<u>Pressure Inches Hg</u>	<u>Flow lb/sec</u>	<u>Preheater Power, KW</u>	<u>Boiler Power, KW</u>
140	.05	5	Increase until first instability occurs. Take full reading showing limits of those parameters which are oscillating.
140	.05	5	Slowly increase until stable boiling begins. Take full reading.
140	.05	4.5	Increase by 0.5 KW above previous setting. Take full reading.
140	.05	4.0	Increase by 0.5 KW above previous setting. Take full reading.
140	.05	3.5	Increase by 0.5 KW above previous setting. Take full reading.
			Continue decreasing pre-heater power and in- creasing boiler power in increments of 0.5 KW until pre-heater is at minimum setting. At this point, increase boiler power in small in- (taking readings at each level) until unstable boiling begins. The pressure levels to be tested are 100, 120, 140, 160 and 180 inches Hg. A. Flow will be varied as time permits.

TABLE 9

300 KW LOOP PERFORMANCE INSTRUMENTATION LOCATIONS  
COMMENCING APRIL, 1964

Sensor Location	Thermocouple Code Number	Ref. Temp.	Rubicon Switch	Digital Scanner Channel
Not Used				01
Cats Block 1-1A (K)		ICE	H5	02
Cats Block 1-1B (K)		ICE	H6	03
Cats Block 1-2 (CC)		ICE	H7	04
Cats Block 1-3 (CC)		ICE	H8	05
Cats Block 1-4 (CC)		ICE	H9	06
Cats Block 2-1 (CC)		ICE	H10	07
Cats Block 2-2A (K)		ICE	H11	08
Cats Block 2-2B (K)		ICE	H12	09
Hor. Cond. Exit Well	3-122-G-S-H13	ICE	H13	10
Secondary Inlet Well	1-102-P-S-H1	ICE	H1	11
Secondary Exit Well	1-104-Z-S-H2	ICE	H2	12
Primary Inlet Well	1-106-W-S-H3	ICE	H3	13
Primary Exit Well	1-107-T-S-H4	ICE	H4	14
Not Used				15
Not Used				16
Secondary Inlet Well	1-102-N-S-B34	ICE	B34	17
Secondary Inlet Well	1-102-O-S-B35	ICE	B35	18
Secondary Exit Well	1-104-X-S-B37	ICE	B37	19
Secondary Exit Well	1-104-Y-S-B39	ICE	B39	20
Primary Inlet Well	1-106-V-S-C1	ICE	C1	21
Primary Inlet Well	1-106-V-S-C2	ICE	C2	22
Primary Exit Well	1-107-R-S-C4	ICE	C4	23
Primary Exit Well	1-107-S-S-C5	ICE	C5	24
Boiler Shell Top North	1-23-072-S-C7	ICE	C7	25
Boiler Shell Top South	1-23-216-S-C8	ICE	C8	26
Boiler Shell Middle North	1-58-072-S-C9	ICE	C9	27
Boiler Shell Middle South	1-58-216-S-C10	ICE	C10	28
Boiler Shell Bottom North	1-91-072-S-C11	ICE	C11	29
Boiler Shell Bottom South	1-91-216-S-C12	ICE	C12	30
Not Used		1-3-20	C13	31
Thermal Pressure Sensors Braze		1-3-21	C14	32
Thermal Pressure Sensor		1-3-22	C15	33
		1-3-23	C16	34
Insert Leak Indicator		1-3-24	C17	35
Boiler Shell (Top)	1-23-000-S-C18	1-3-25	C18	36
"	1-23-072-S-C19	1-3-26	C19	37
"	1-23-144-S-C20	1-3-27	C20	38
"	1-23-216-S-C21	1-3-28	C21	39
"	1-23-288-S-C22	1-3-29	C22	40

TABLE 9 - (Continued)

Sensor Location	Thermocouple Code Number	Ref. Temp.	Rubicon Switch	Digital Scanner Channel
Boiler Shell (Top)	1-29-000-S-C23	1-3-30	C23	41
"	1-29-072-S-C24	1-3-31	C24	42
"	1-29-144-S-C25	1-3-32	C25	43
"	1-29-216-S-C26	1-3-33	C26	44
"	1-29-288-S-C27	1-3-34	C27	45
"	1-36-000-S-C28	1-3-35	C28	46
"	1-36-072-S-C29	1-3-36	C29	47
"	1-36-144-S-C30	1-3-37	C30	48
"	1-36-216-S-C31	1-3-38	C31	49
"	1-36-288-S-C32	1-3-39	C32	50
"	1-43-000-S-C33	1-3-40	C33	51
"	1-43-072-S-C34	1-3-41	C34	52
"	1-43-144-S-C35	1-3-42	C35	53
"	1-43-216-S-C36	1-3-43	C36	54
"	1-43-288-S-C37	1-3-44	C37	55
"	1-50-000-S-C38	1-3-45	C38	56
"	1-50-072-S-C39	1-3-46	C39	57
"	1-50-144-S-C40	1-3-7	C40	58
"	1-50-216-S	1-3-48	-	59
"	1-50-288-S-F1	1-4-1	F1	60
"	1-58-000-S-F2	1-4-2	F2	61
"	1-58-072-S-F3	1-4-3	F3	62
"	1-58-144-S-F4	1-4-4	F4	63
"	1-58-216-S-F5	1-4-5	F5	64
"	1-58-288-S-F6	1-4-6	F6	65
"	1-63-000-S-F7	1-4-7	F7	66
"	1-63-072-S-F8	1-4-8	F8	67
"	1-63-144-S-F9	1-4-9	F9	68
"	1-63-216-S-F10	1-4-10	F10	69
"	1-63-288-S-F11	1-4-11	F11	70
"	1-70-000-S-F12	1-4-12	F12	71
"	1-70-072-S-F13	1-4-13	F13	72
"	1-70-144-S-F14	1-4-14	F14	73
"	1-70-216-S-F15	1-4-15	F15	74
"	1-70-288-S-F16	1-4-16	F16	75
"	1-77-000-S-F17	1-4-17	F17	76
"	1-77-072-S-F18	1-4-18	F18	77
"	1-77-144-S-F19	1-3-10	F19	78
"	1-77-216-S-F20	1-4-20	F20	79
"	1-77-288-S-F21	1-4-21	F21	80
"	1-84-000-S-F22	1-4-22	F22	81
"	1-84-072-S-F23	1-4-23	F23	82

TABLE 9 - (Continued)

Sensor Location	Thermocouple Code Number	Ref. Temp.	Rubicon Switch	Digital Scanner Channel
Boiler Shell (Bottom)				
"	1-84-144-S-F24	1-4-24	F24	83
"	1-84-216-S-F25	1-4-25	F25	84
"	1-84-288-S-G1	1-4-26	G1	85
"	1-91-000-S-G2	1-4-27	G2	86
"	1-91-072-S-G3	1-4-28	G3	87
"	1-81-144-S-G4	1-4-29	G4	88
"	1-91-216-S-G5	1-4-30	G5	89
"	1-91-288-S-G6	1-4-31	G6	90
Vert. Cond. Inlet Well	2-109-M-S-H26	ICE	H26	91
Vert. Cond. Exit Well	2-111-H-S-H25	ICE	H25	92
Not Used			G9	93
Cats Block 1-1 (new CC)		ICE	G10	94
Short Circuit			G11	95
Cats Block 2-2 (new CC)		ICE	G12	96
Not Used			G13	97
Primary Flow Meter			G14	98
Secondary Flow Meter			G15	99
Short Circuit				100
Vertical Condenser Tube Wall	2-1-12-S-B13	2-1-1	B13	101
"	2-7-4:30-S-B18	2-1-3	B18	102
"	2-5-7:30-S-B16	2-1-5	B16	103
"	2-5-1:30-S-B17	2-1-2	B17	104
"	2-1-6-S-B14	2-1-6	B14	105
"	2-3-10:30-S-B15	2-1-4	B15	106
"	2-9-3-S-B19	2-1-7	B19	107
Vertical Condenser Tube Wall	2-9-9-S-B20	2-1-8	B20	108
Vertical Condenser Inlet Well	2-109-L-S-B24	ICE	B24	109
Vertical Condenser Inlet Well	2-109-K-S-B11	ICE	B11	110
Hor. Cond. Bulk Air Exit (at Hood-S)		2-1-11	B12	111
Not Used			B21	112
Vertical Cond. Exit Well	2-111-J-S-B22	ICE	B22	113
Vertical Cond. Exit Well	2-111-I-S-B23	ICE	B23	114
Hor. Cond. Exit Well	3-112-F-S-B32	ICE	B32	115
Hor. Cond. Exit Well (New)	3-112-E-S-B33	ICE	B33	116
Not Used		1-1-1	B25	117
Not Used		1-1-2	B26	118
Not Used		1-1-3	B27	119
Not Used		1-1-4	B28	120
Not Used			N1	121
Not Used			N2	122
Not Used			N3	123
Boiler Exit Pressure			N4	124
Not Used			N5	125

TABLE 9 - (Continued)

Sensor Location	Thermocouple Code Number	Ref. Temp.	Rubicon Switch	Digital Scanner Channel
Not Used			N6	126
Not Used			N7	127
Not Used			N8	128
Boiler Inlet Pressure			N9	129
Short Circuit		2-2-48	A1	131
Short Circuit		2-2-50	A2	132
Horz. Cond. Annulus Air	3-12-9-K-A2	2-2-51	A3	133
Vertical Cond. Annulus Air	2-4-3-K-A3	2-2-52	A4	134
"	2-4-9-K-A4	2-2-53	A5	135
"	2-6-3-K-A5	2-2-54	A6	136
Horz. Cond. Bulk Air Exit (at Hood-K)	2-8-3-K-A7	2-2-55	A7	137
Vert. Cond. Annulus Air	2-8-9-K-A8	2-2-56	A8	138
Vert. Cond. Annulus Air	1-25-3.5-K-A9	1-1-5	A9	139
Not Used	1-25-7.5-K-A10	1-1-6	A10	140
Not Used	1-36-3.5-K-A11	1-1-7	A11	141
Not Used	1-36-7.5-K-A12	1-1-8	A12	142
Boiler Hanger T/C		1-1-9	A13	143
Boiler Bellows Zone T/C		1-1-10	A14	144
Boiler Bellows Zone T/C		1-1-11	A15	145
Boiler Bellows Zone T/C		1-1-12	A16	146
Hor. Cond. Bulk Air Exit (Under Hood-West)		2-2-65	A17	147
Hor. Cond. Bulk Air Exit (Under Hood-North)		2-2-66	A18	148
Vert. Condenser Bulk Air In	2-L-6-K-A19	2-2-67	A19	149
"	2-M-6-K-A20	2-2-68	A20	150
Vert. Condenser Bulk Air Out	2-N-6-K-A21	2-2-69	A21	151
"	2-D-6-K-A22	2-2-70	A22	152
Hor. Condenser Bulk Air In	3-S-12-K-A23	2-2-71	A23	153
"	3-T-6-K-A24	2-2-72	A24	154
Hor. Condenser Bulk Air Exit - North		2-2-73	A25	155
Hor. Condenser Bulk Air Exit North East		2-2-74	A26	156
Hor. Condenser Bulk Air Exit South		2-2-75	A27	157
Hor. Condenser Annulus Air	3-2-9-K-A28	2-2-76	A28	158
Hor. Condenser Annulus Air	3-4-3-K-A29	2-2-77	A29	159
Hor. Condenser Annulus Air	3-4-9-K-A30	2-2-78	A30	160
Hor. Condenser Annulus Air	3-4-6-K-A31	2-2-79	A31	161
Boiler Inlet Press. Gage T/C		2-2-80	A32	162
Hor. Condenser Annulus Air	3-7-3-K-A33	2-2-81	A33	163
Vert. Cond. Cooling Air Orifice "B"		2-2-82	A34	164
Hor. Cond. Annulus Air	3-8-3-K-A35	2-2-83	A35	165
"	3-8-9-K-A36	2-2-84	A36	166
Not Used		2-2-85	A37	167

TABLE 9 - (Continued)

Sensor Location	Thermocouple Code Number	Ref. Temp.	Rubicon Switch	Digital Scanner Channel
Boiler Exit Pressure Gage T/C		2-2-86	A38	168
Hor. Cond. Cooling Air Orifice "A" Downstream		2-2-87	A39	169
Not Used	3-13-9-K-B1	2-2-88	B1	170
Not Used		2-2-89	B2	171
Hor. Cond. Annulus Air Upstream	3-12-9-K-B3	2-2-90	B3	172
Vert. Cond. Cooling Air Orifice "A"		2-2-91	B4	173
Hro. Cond. Cooling Air Orifice "B" Downstream		2-2-92	B5	174
Hor. Cond. Cooling Air Orifice "A" Upstream		2-2-93	B6	175
Hor. Cond. Annulus Air	3-15-9-K-B7	2-2-94	B7	176
Hor. Cond. Bulk Air Exit Upper	3-U-12-K-B8	2-2-95	B8	177
Hor. Cond. Bulk Air Exit Lower	3-V-6-K-B9	2-2-96	B9	178
Primary Flow Meter Stream Temp.		1-1-26	E2	179
Primary Flow Meter Magnet Temp.		1-1-27	E2	180
Secondary Flow Meter Stream Temp.		1-1-28	E3	181
Secondary Flow Meter Magnet Temp.		1-1-29	E4	182
Vert. Cond. Outer Skin Upstream Temp.		1-1-30	E5	183
Vert. Cond. Outer Skin Downstream Temp.		1-1-31	E6	184
Hor. Cond. Outer Skin Upstream Temp.		1-1-32	E7	185
Hor. Cond. Outer Skin Downstream Temp.		1-1-33	E8	186
Not Used	1-1-34	1-1-34	E9	187
Boiler Insert #1	1-91-000-K-E10	1-1-35	E10	188
Boiler Insert #2	1-77-000-K-E11	1-1-36	E11	189
Boiler Insert #3	1-63-000-K-E12	1-1-37	E12	190
Boiler Insert #4	1-49-000-K-E13	1-1-38	E13	191
Boiler Insert #5	1-35-000-K-E14	1-1-39	E14	192
Boiler Insert #6	1-21-000-K-E15	1-1-40	E15	193
Boiler Insert No. 7	1-13-000-K-E16	1-1-41	E16	194

Test Section 
 1 = Boiler  
 2 = Horizontal Condenser  
 3 = Vertical Condenser
   
 Distance from reference plane (See Figure 29)  
 Circumferential position: Quadrant - 0' clock - Degrees  
 T/C alloy: S=Pt10%Rh-Pt; K Chromel Alumel  
 CC = Copper Constantan  
 Rubicon Switch Position  
 I - 80 - 1 - S - C25                      Code Number Description

TABLE 10

COMPARISON OF HIGH TEMPERATURE DIFFERENTIAL  
PRESSURE TRANSDUCER PERFORMANCE

<u>ITEM</u>		Stressed Diaphragm (1000°F) (Consolidated Controls Corporation)	Slack Diaphragm (1200°F) (Taylor Instrument Company)
1. System Cost	\$2,500	\$2,200	
2. Transducer Operating Temperature Limit, °F	900	1,200	
3. Nominal Full Scale Range, psi	15	15	
4. Calibrated accuracy capability at a fixed temperature, including linearity and hysteresis, % of full scale	+ 1 <sup>(1)</sup>	+ 1 <sup>(1)</sup>	
5. Long Term Stability, change in calibration at operating temperatures, % of full scale per week.	+ 1.0 <sup>(2)</sup>	+ 0.1 <sup>(1, 2)</sup>	
6. Temperature Stability, change in calibration per °F change in transducer temperature, % of full scale.	+ 0.0035 <sup>(1)</sup>	+ 0.001 <sup>(1)</sup>	
7. Ambient Temperature Effect change over 50-- 150°F range, % of full scale.	+ 0.5 <sup>(1)</sup>	+ 1.0 <sup>(1)</sup>	
8. Response Time for 63.2% of step change at transducer, seconds	.001 <sup>(1)</sup>	1.0 <sup>(1)</sup>	
9. Overrange Capability with no permanent damage to measuring system, psi	22.5 <sup>(1)</sup>	150 <sup>(1)</sup>	

1 - Based on manufacturer's claims

2 - Based on G.E. experience

TABLE 11

Points taken from EMF - Temperature characteristic curve for W3% Re Vs. W26% Re thermocouple wire based on GE calibration in an argon atmosphere using a calibrated Pt 10% Rh--Pt thermocouple as a reference standard.

Reference Temperature: 32°F  
W3% Re Wire: GE Company 3D 218 CS .005" Dia.  
W26% Re Wire: Hoskins Company .005" Dia.

<u>Temp.</u> <u>°F</u>	<u>Output</u> <u>Millivolts</u>
32	0
125.2	0.5
203.8	1.0
272.2	1.5
336.5	2.0
398.5	2.5
455.7	3.0
512.9	3.5
565.9	4.0
617.9	4.5
670.0	5.0
719.6	5.5
768.8	6.0
817.5	6.5
865.8	7.0
913.6	7.5
960.1	8.0
1006.2	8.5
1053.7	9.0
1099.9	9.5
1144.7	10.0
1190.2	10.5
1237.0	11.0
1283.5	11.5
1329.6	12.0
1375.3	12.5
1421.4	13.0
1467.2	13.5
1511.8	14.0
1557.7	14.5

TABLE 11 - (Continued)

<u>Temp.</u> <u>°F</u>	<u>Output</u> <u>Millivolts</u>
1604.0	15.0
1650.0	15.5
1696.4	16.0
1742.5	16.5
1788.2	17.0
1833.5	17.5
1879.4	18.0
1924.8	18.5
1970.7	19.0
2016.4	19.5
2064.0	20.0
2116.6	20.5
2158.2	21.0

TABLE 12

RESULTS OF SPECTROGRAPHIC ANALYSIS OF SURFACES  
OF Mo-0.5Ti ALLOY TUBE FROM THE 300 KW LOOP

	Relative Concentrations			
	10-100%	1-10%	1%	Not Detected
<u>Unpolished Surface</u>				
Sodium Side (OD)	Co	Cr,Fe,Ni	- -	W, Cb, Zr
Potassium Side (ID)	- -	Co	Cr,Fe,Ni	W, Cb, Zr
<u>Polished* Surface</u>				
Sodium Side (OD)		Co	Cr,Fe,Ni	W, Cb, Zr

\*Approximately 2 mils of surface removed.

TABLE 13

FIELD WELDING QUALIFICATION - CHEMICAL ANALYSIS

<u>Condition</u>	Chemical Analysis, ppm			
	O	N	H	C
As received, Cb-1Zr pipe	111	32	8	80
0.75-inch schedule 80, MCN-310	113	34	8	80
Weld metal, as welded, pipe in horizontal position	252	67	5	20 - 30
Filler wire	59	25	1	40

TABLE 14

HARDNESS SURVEY ON 0.75-INCH SCHEDULE 80 Cb-1Zr

ALLOY PIPE FROM ABOVE THE MIXER OF 100 KW Loop

Distance from Inside Surface of Pipe (Mils)	2	4	6	8	12	25	30	35	50
--	---	---	---	---	----	----	----	----	----

Diamond Pyramid Hardness (Load-100 grams)	140	128	125	115	107	97	93	84	84
--	-----	-----	-----	-----	-----	----	----	----	----

TABLE 15

RESULTS OF CHEMICAL ANALYSES ON RING SEGMENTS MACHINED  
FROM 0.75-INCH SCHEDULE 80 PIPE Cb-1Zr ALLOY PIPE TAKEN  
FROM 100 KW FACILITY AFTER ABOUT 3000 HRS OPERATION ABOVE

800°F

Specimen Analyzed	Concentration (ppm)			
	O	N	H	C
Inside 0.050-inch thick ring	1870	79	3	70, 70
Middle 0.050-inch thick ring	277	86	2	80, 90
Outside 0.050-inch thick ring	502	116	3	60, 70
As-received pipe (total cross section)	111, 113	32, 34	8, 8	80, 80

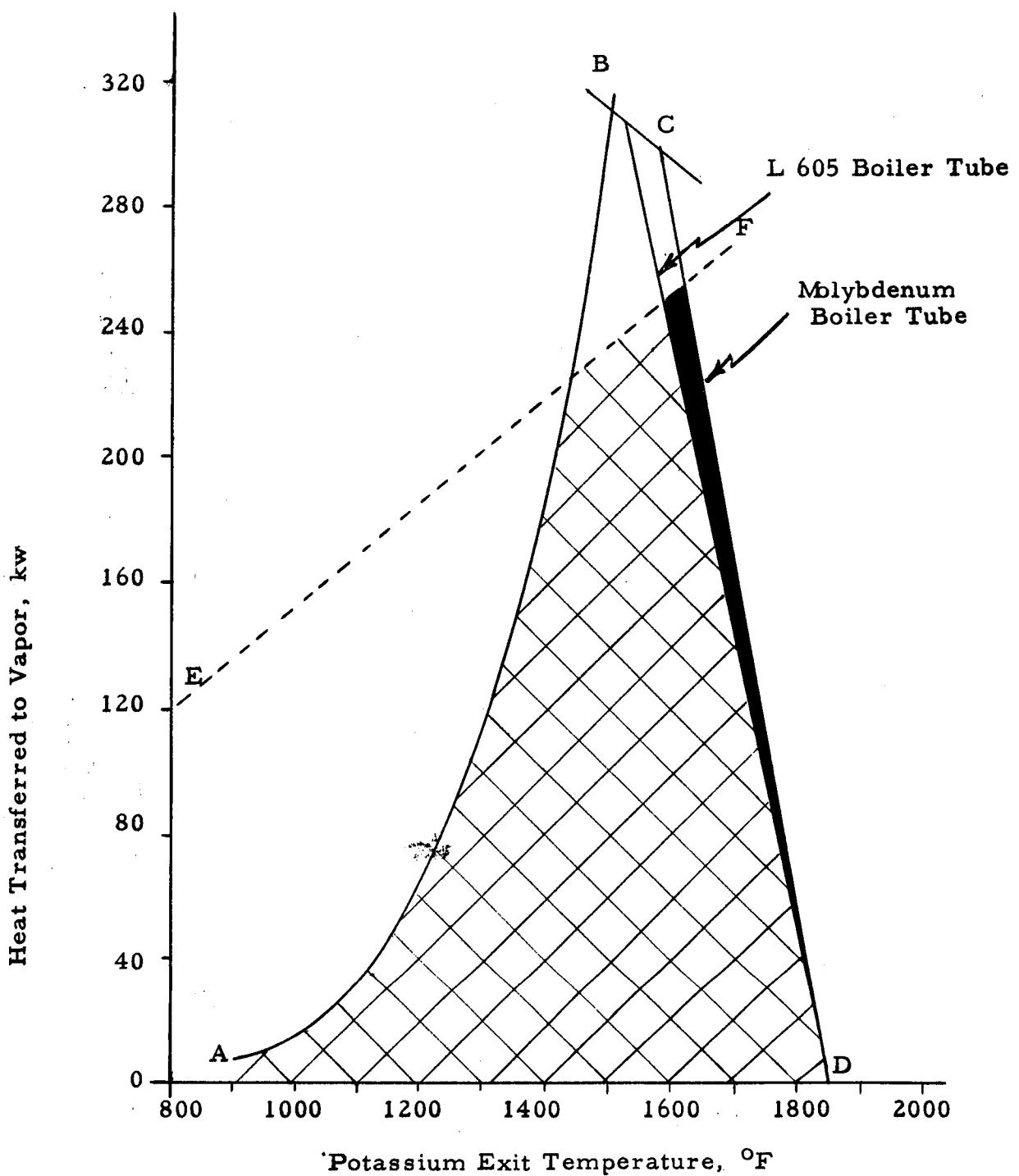


Figure 1. Potential Operating Capability of 300 KW Facility.

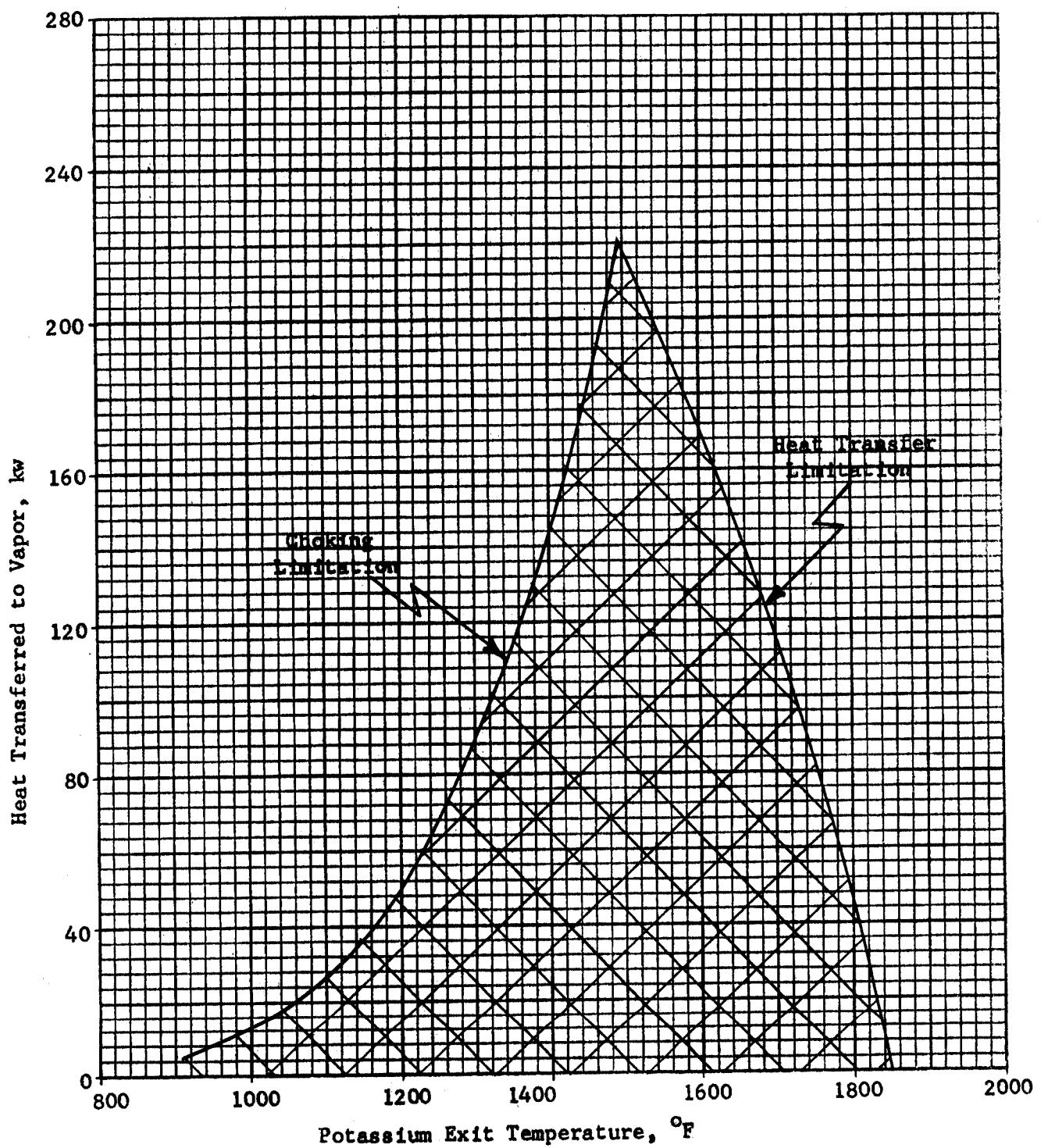


Figure 2. Potential Operating Capability of the 300 KW Boiler  
with 2-inch Pitch Helical Insert.

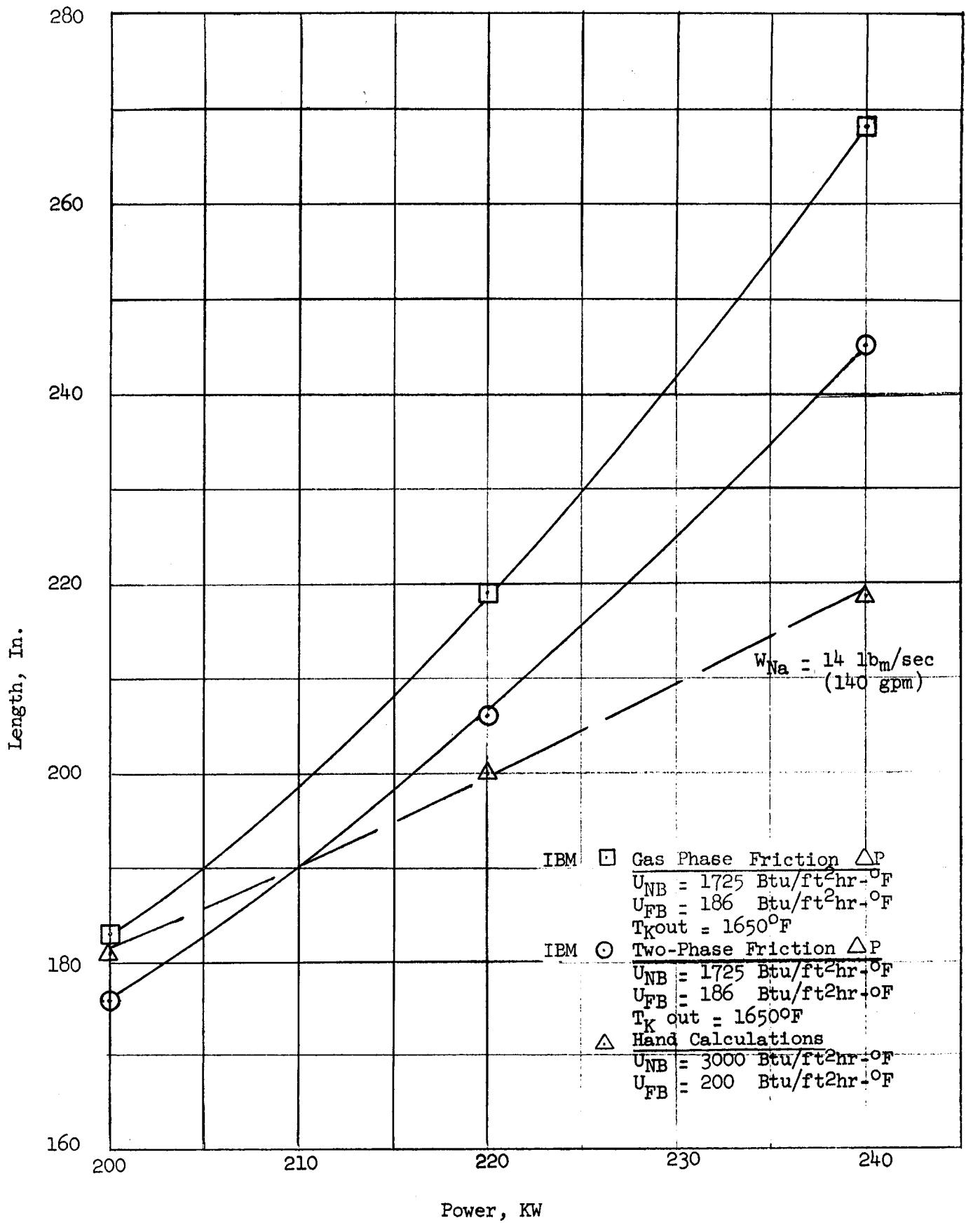


Figure 3. Boiler Tube Length vs. Boiler Power for Different Pressure Drop Assumptions for the 300 KW Facility Multi-Tube Boiler.

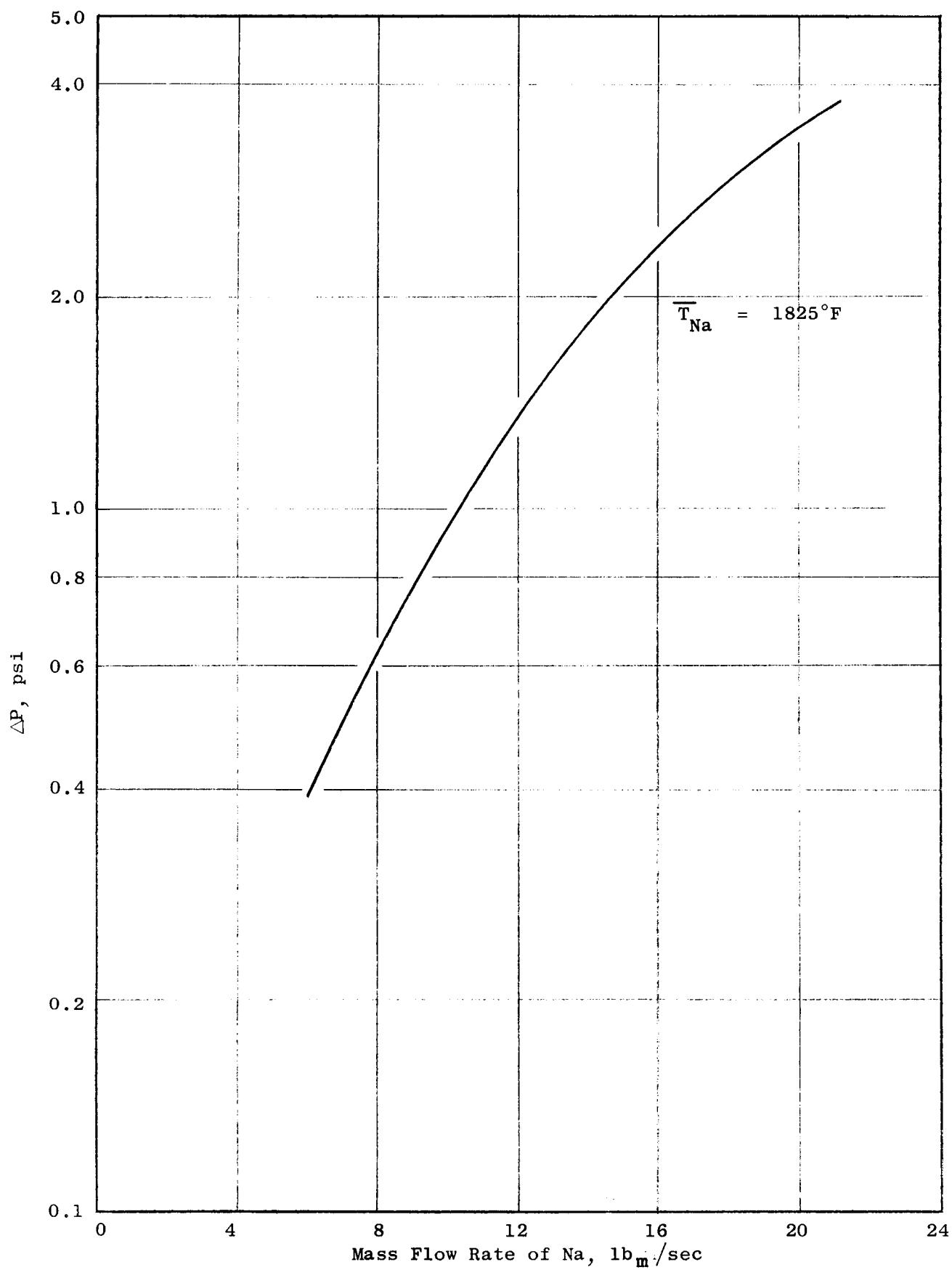


Figure 4. . Sodium Pressure Drop Across Multi-Tube Boiler  
for the 300 KW Facility.

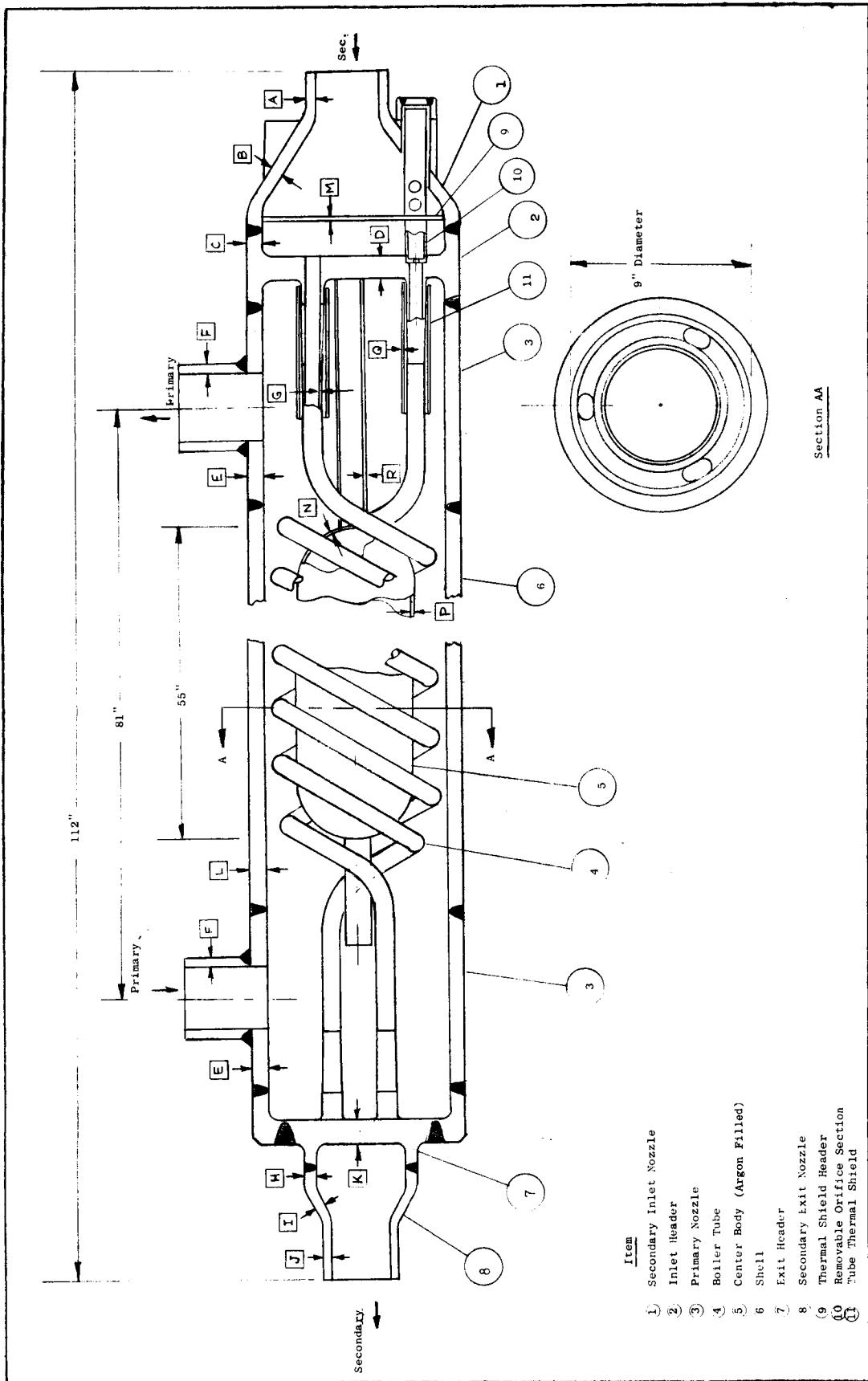


Figure 5. Multiple Coil Tube Test Boiler for the 300 kW Facility.

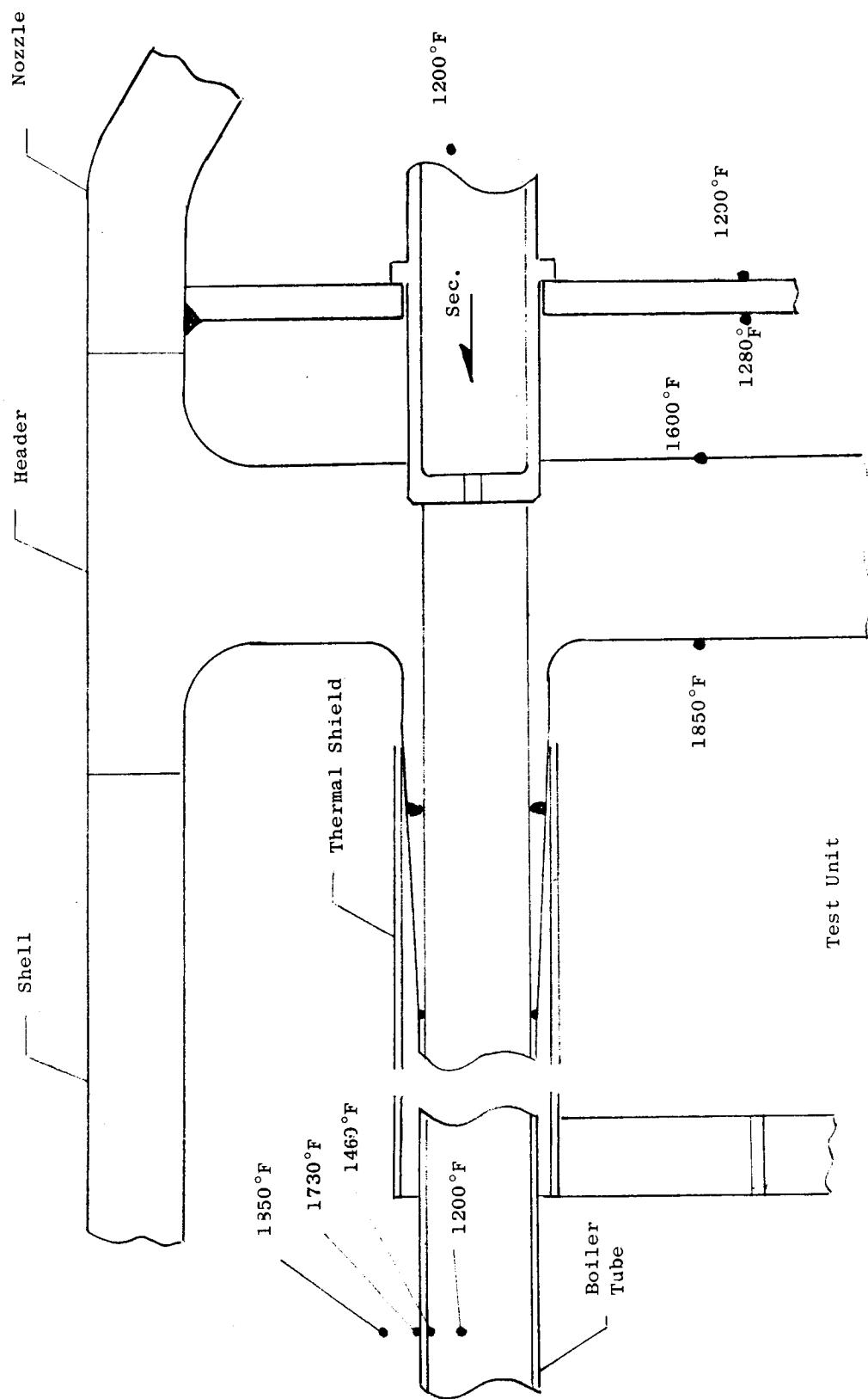


Figure 6. Estimated Temperature Profile in the Multi-tube Boiler for the 300 KW Facility. (Multi-tube Boiler shown in Figure 5).

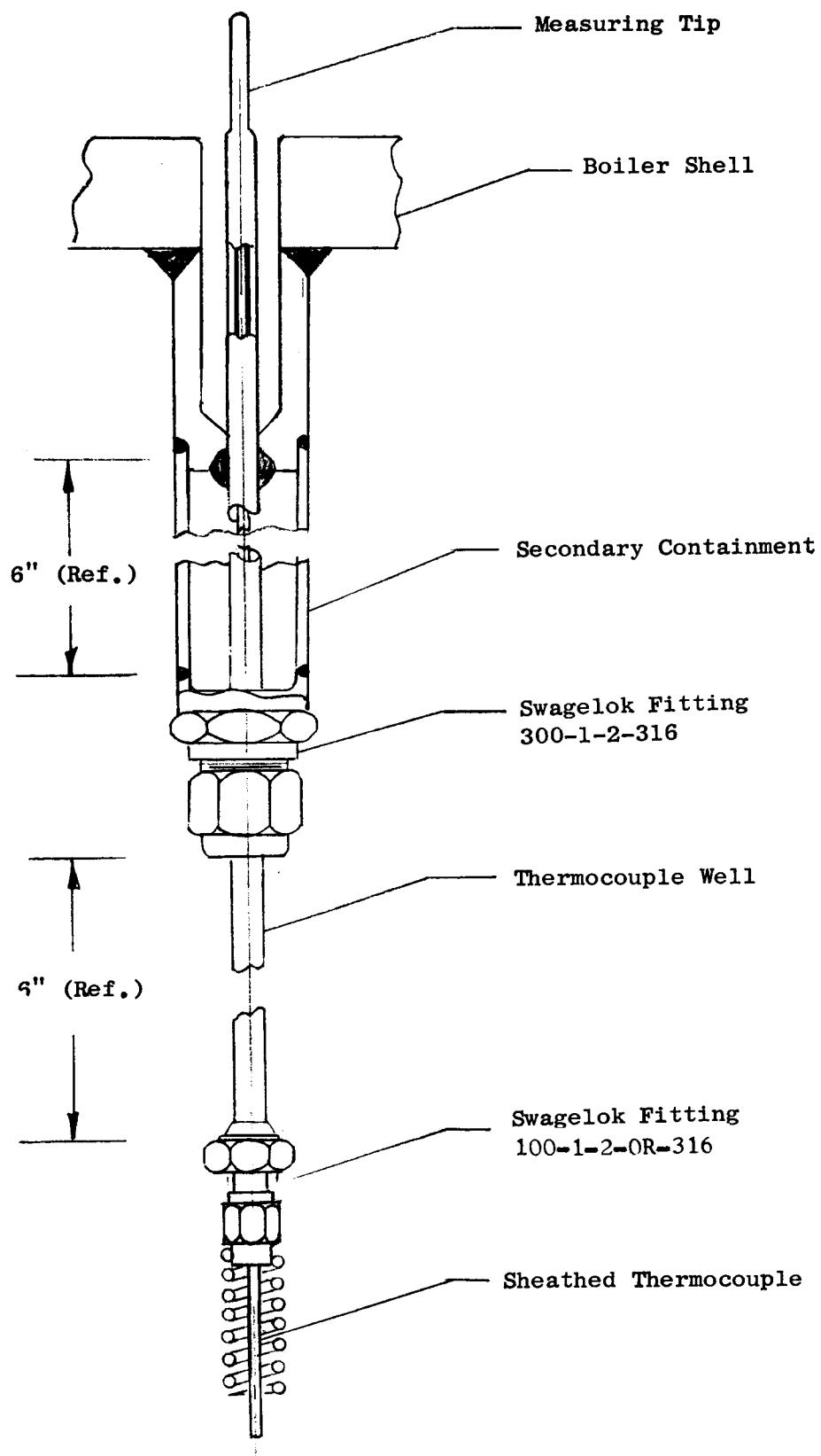


Figure 7. Thermocouple Assembly for the 300 KW Facility.

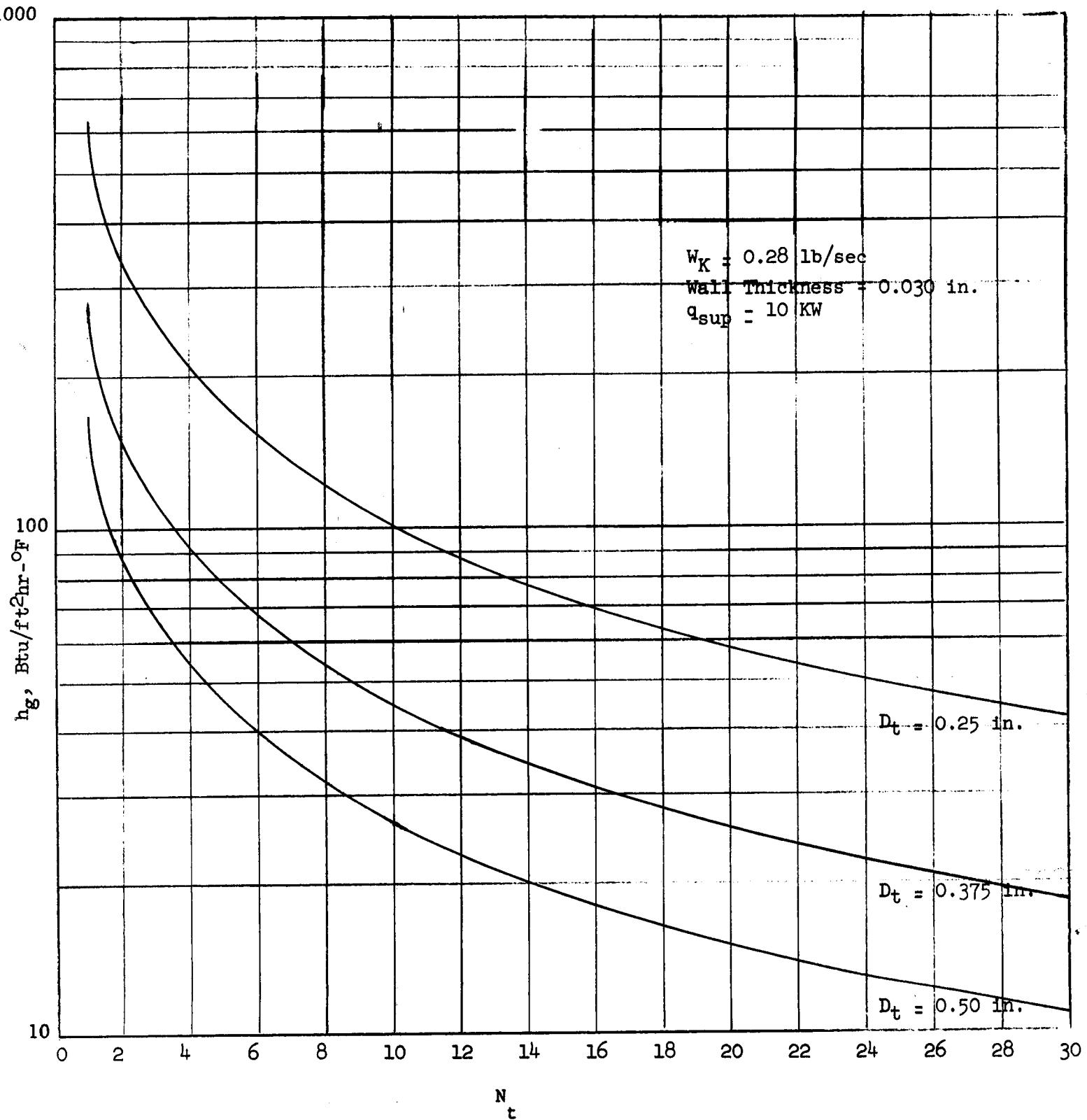


Figure 8. Potassium Heat Transfer Coefficient as a Function of the Number of Tubes with Nominal Tube Diameter as a Parameter for the 300 KW Facility Superheater.

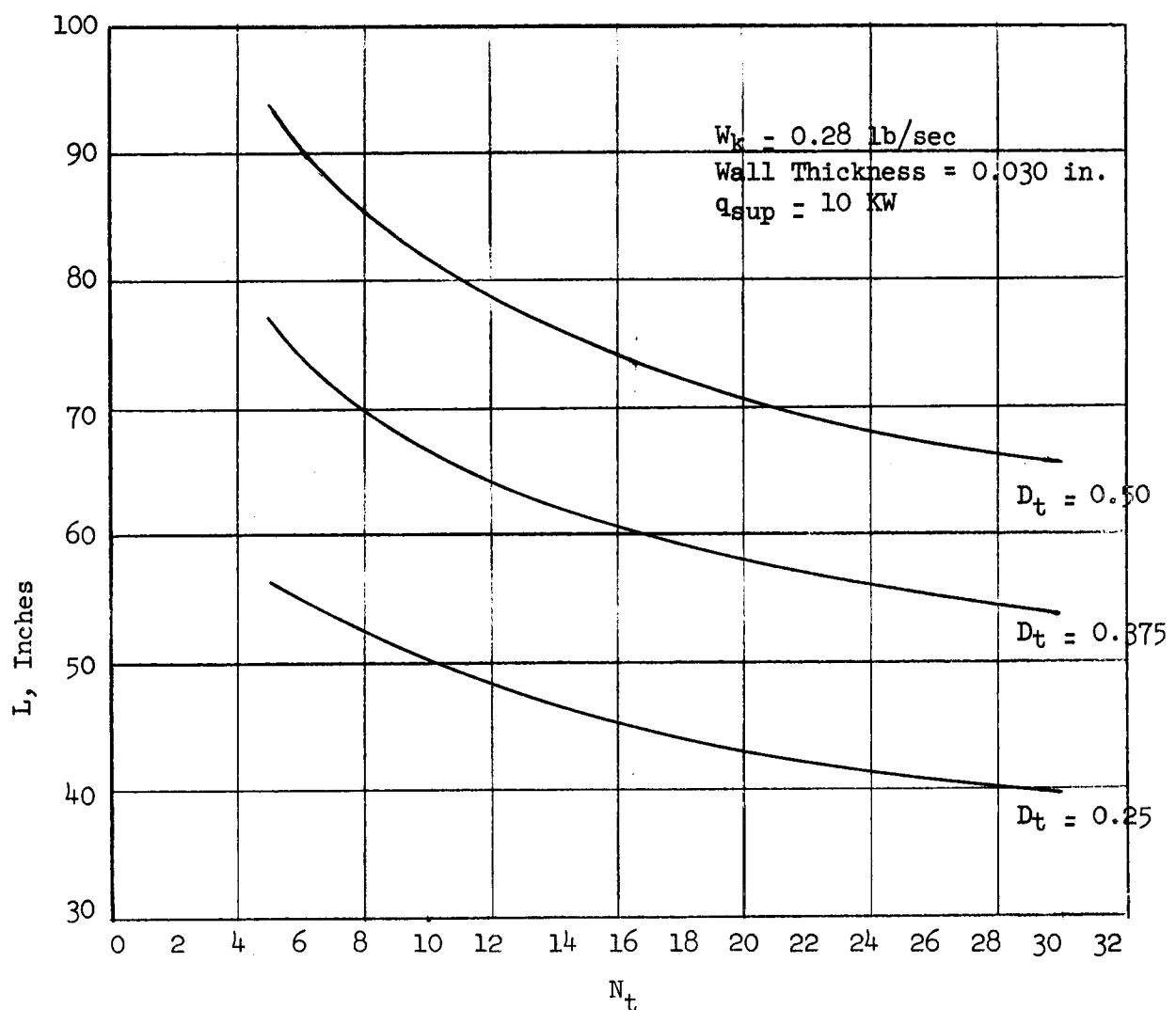


Figure 9. Required Superheater Length Vs.  
Number of Tubes and Tube Diameter  
for 300 KW Facility.

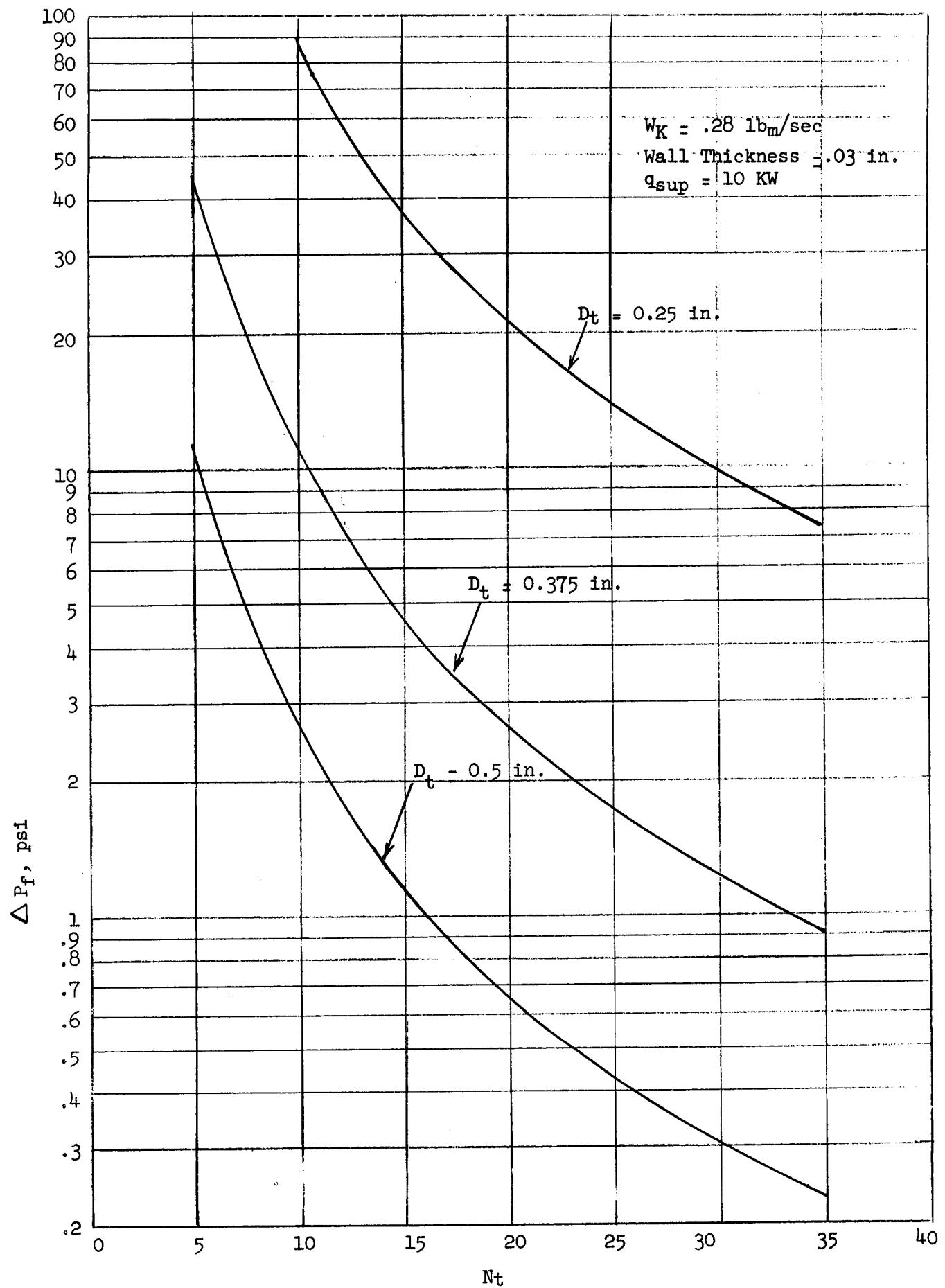


Figure 10. Pressure Drop as a Function of the Number of Tubes for Several Tube Diameters for the 300 KW Facility Superheater.

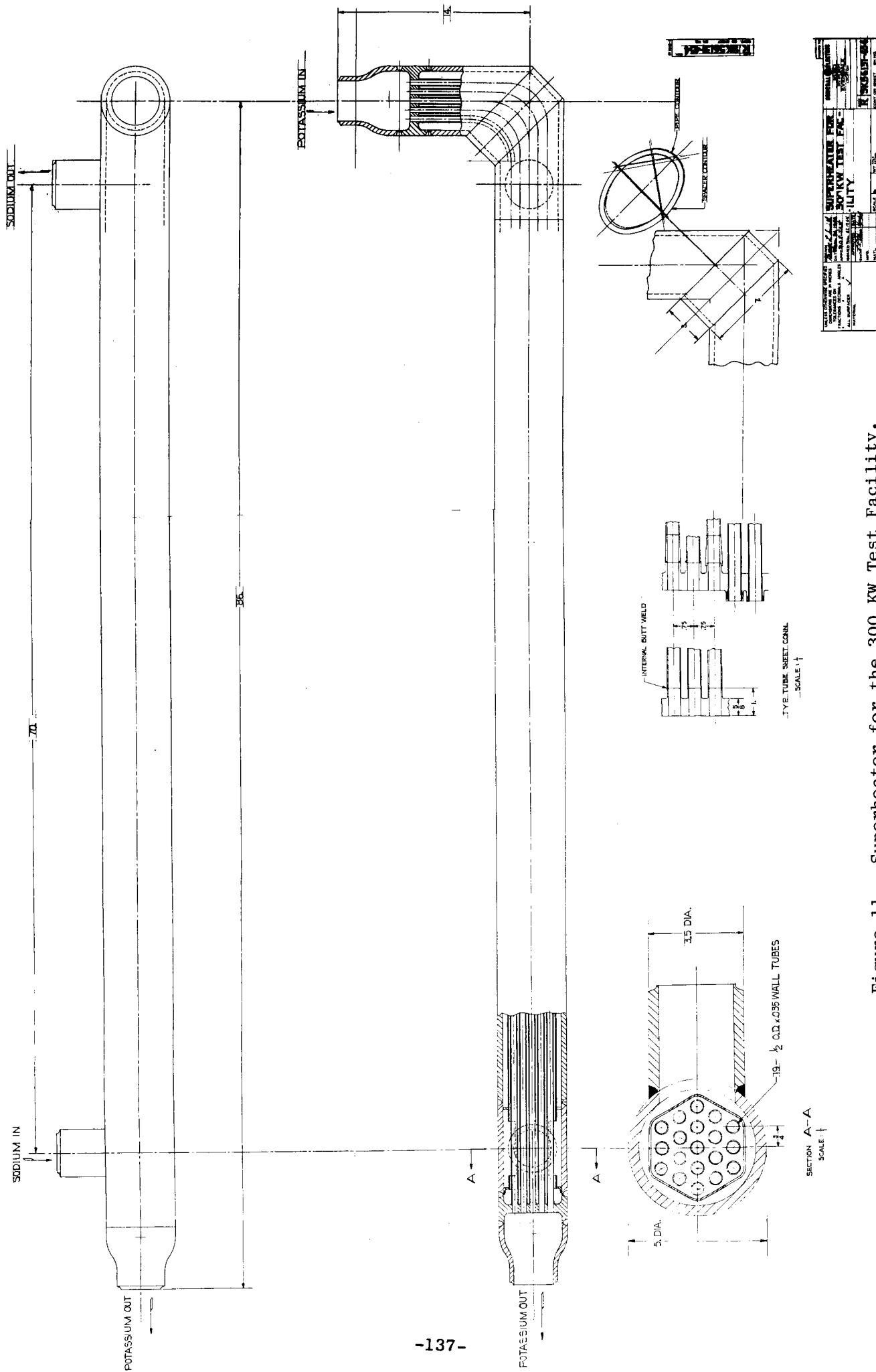


Figure 11. Superheater for the 300 kW Test Facility.

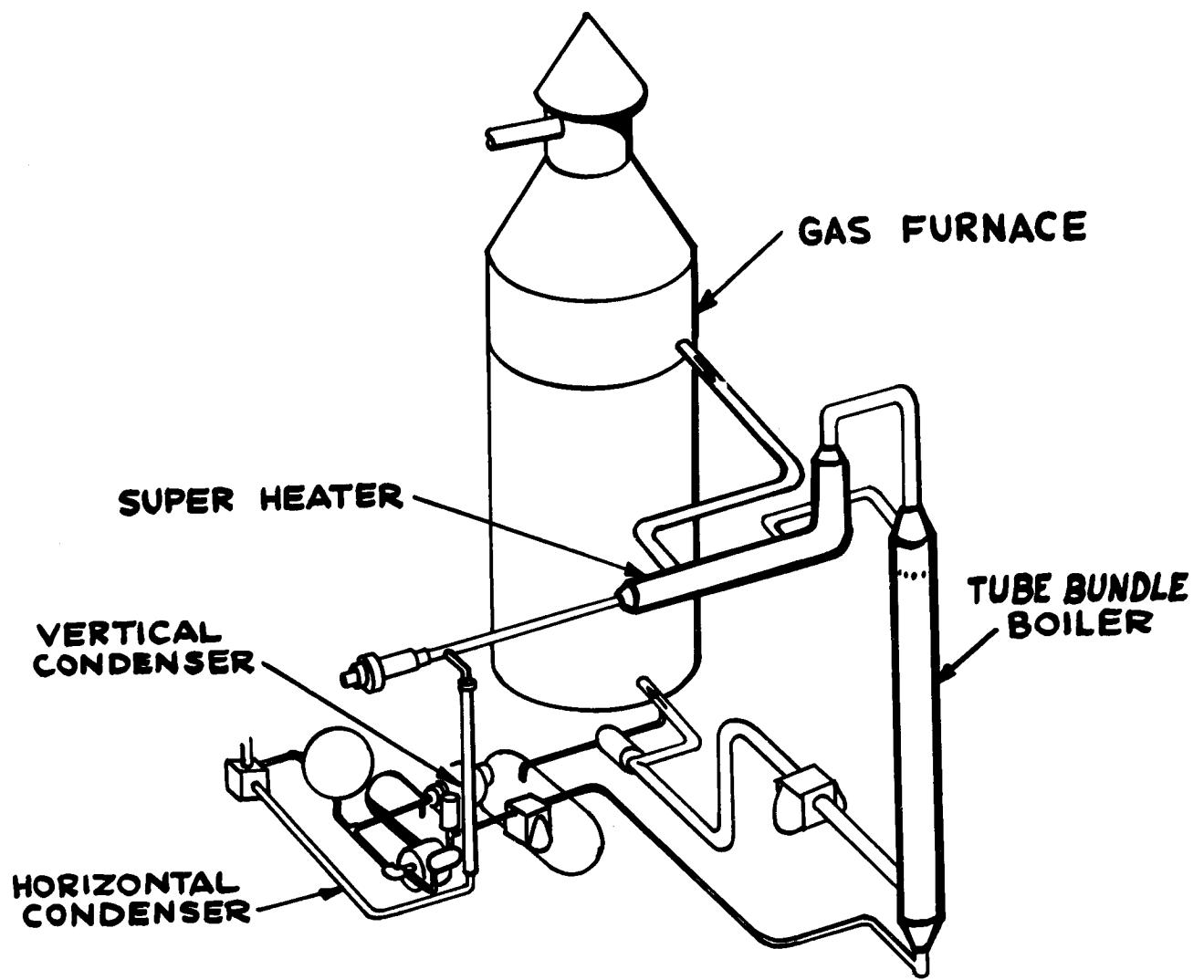


Figure 12. 300 KW Test Boiler-Superheater Installation

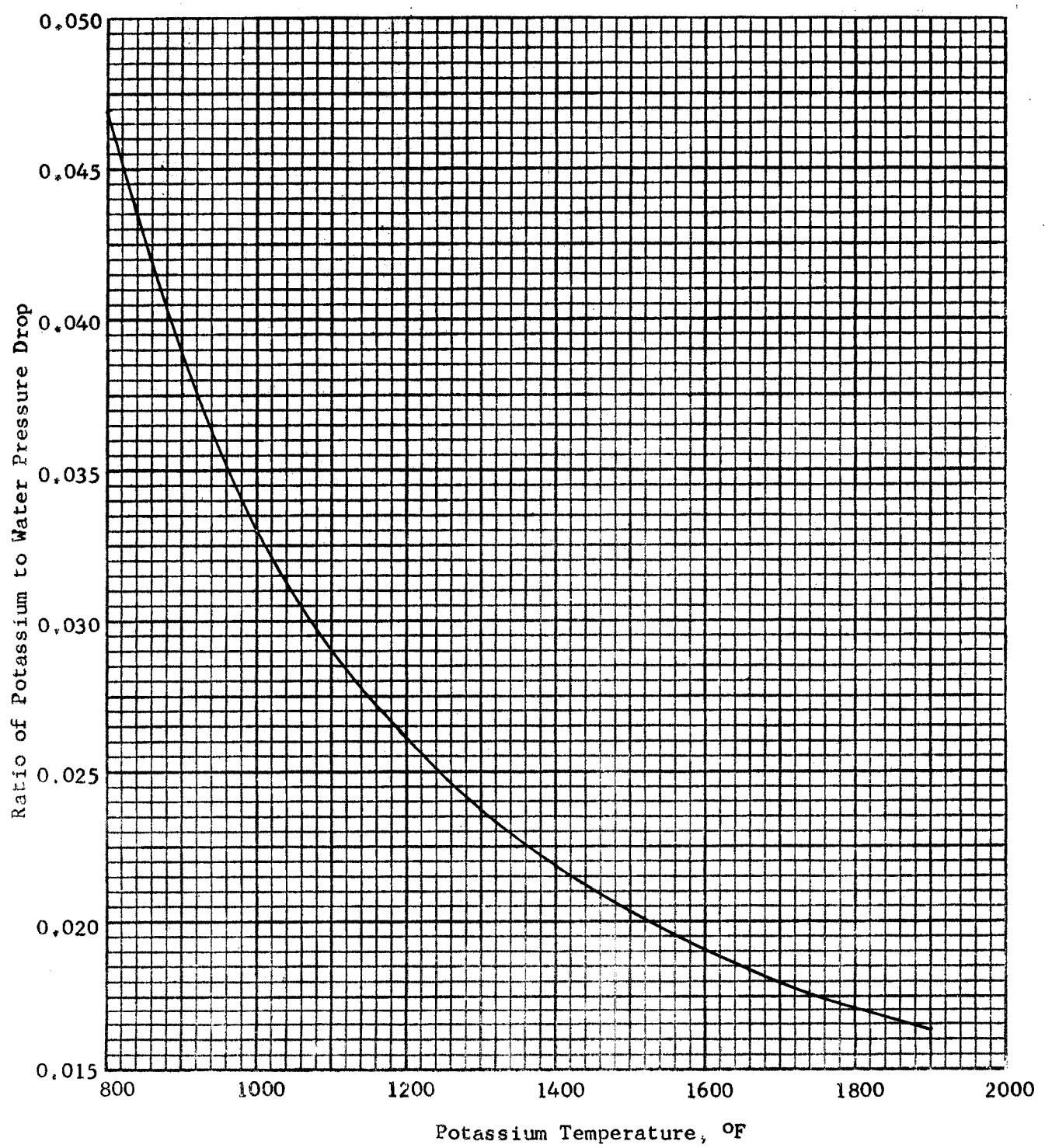


Figure 13. Ratio of Liquid Potassium to Water Pressure Drop for Equal Reynolds Numbers

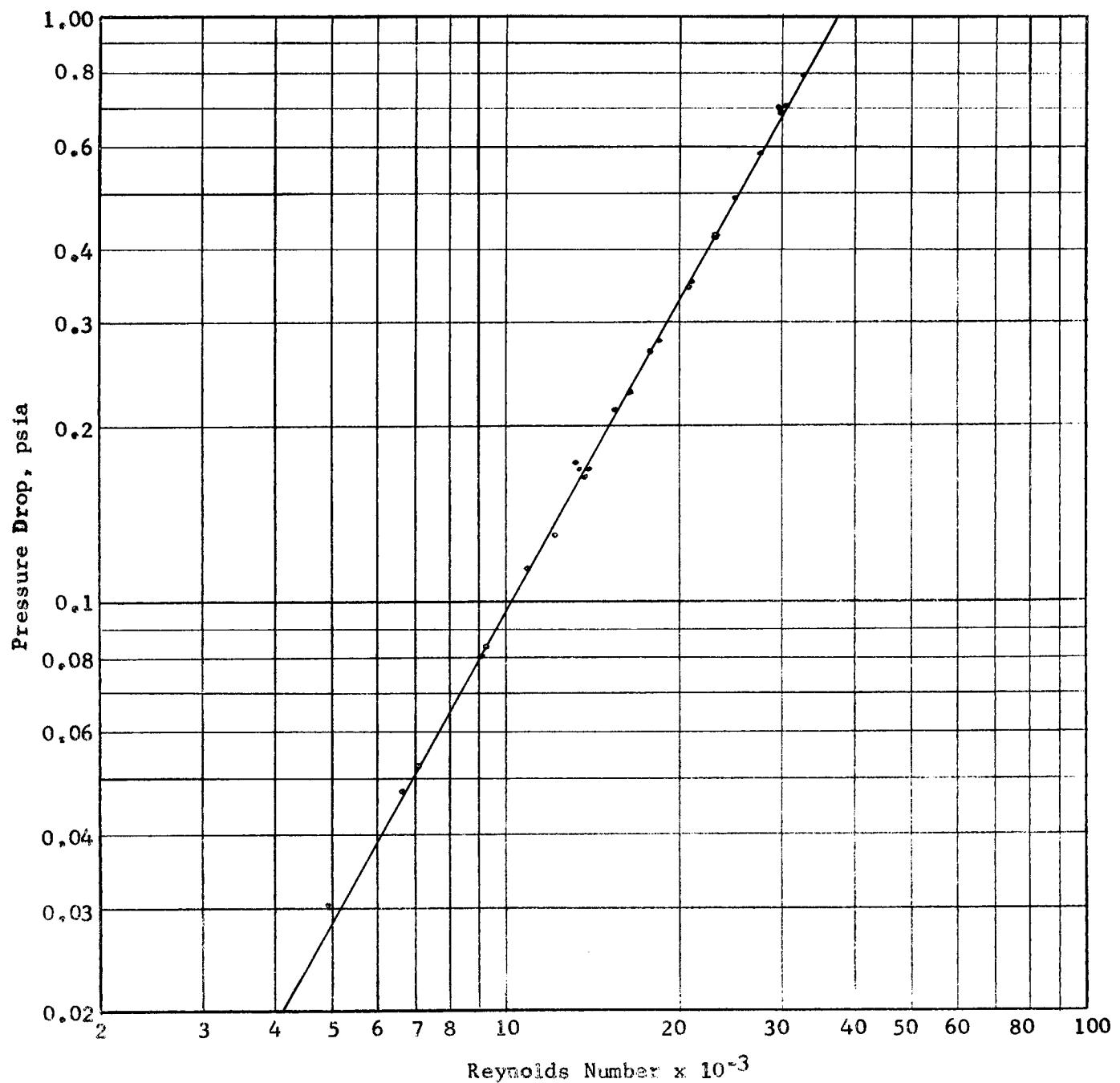


Figure 14. Water Pressure Drop in L-605  
Boiler Tube Without Insert

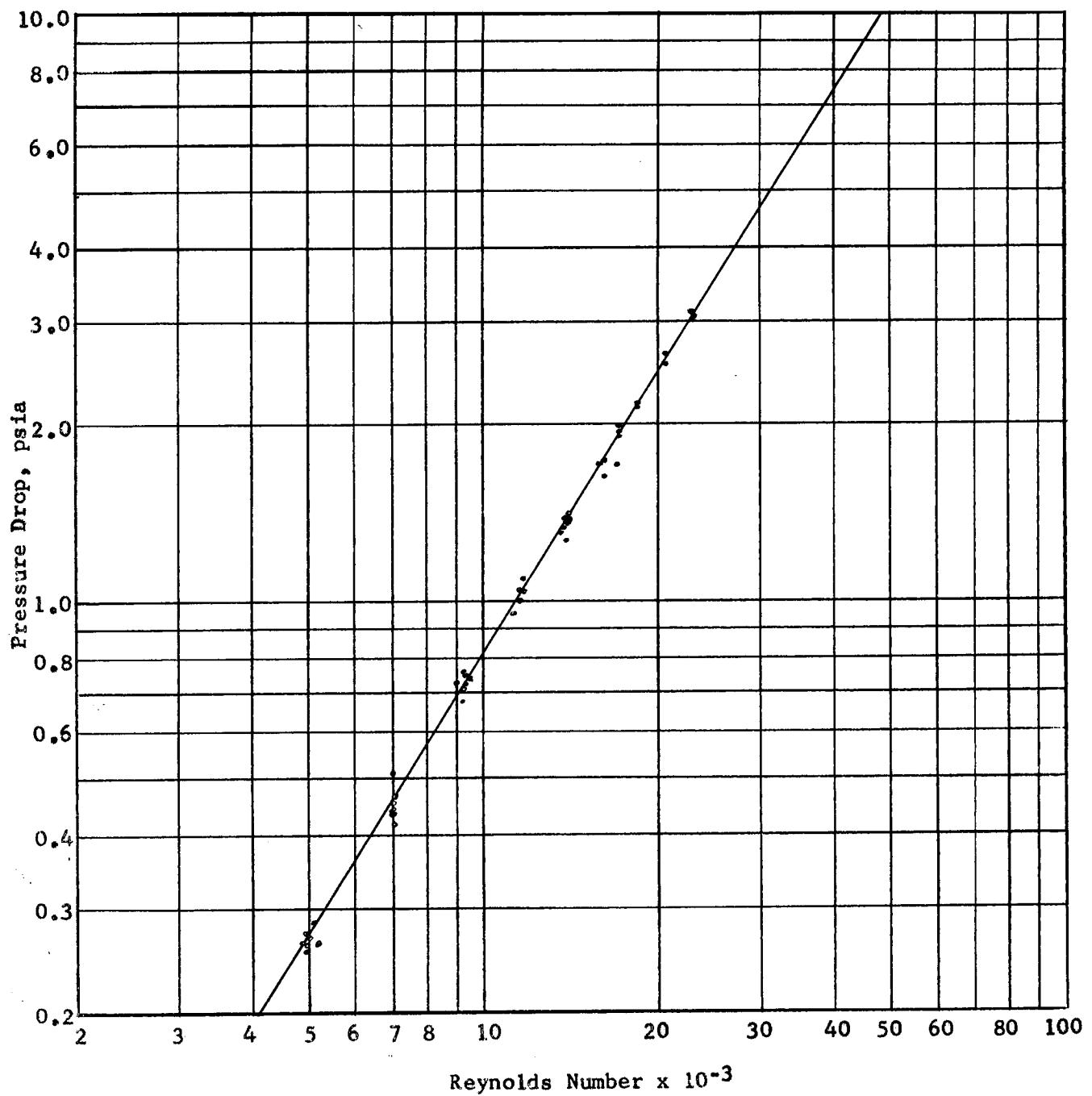


Figure 15. Water Pressure Drop in L-605  
Boiler Tube With Insert

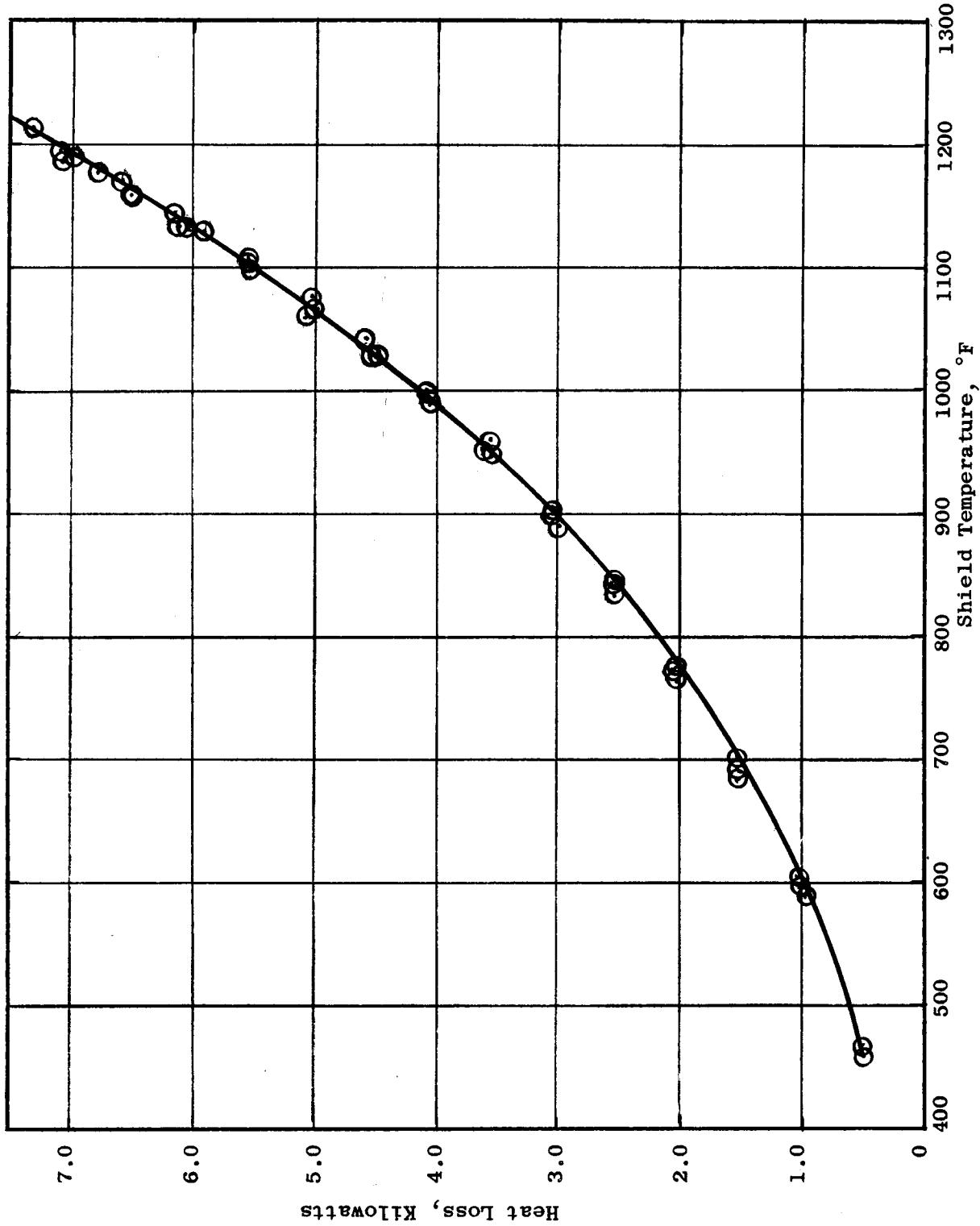


Figure 16. Boiler Heat Loss in the 100 KW Facility

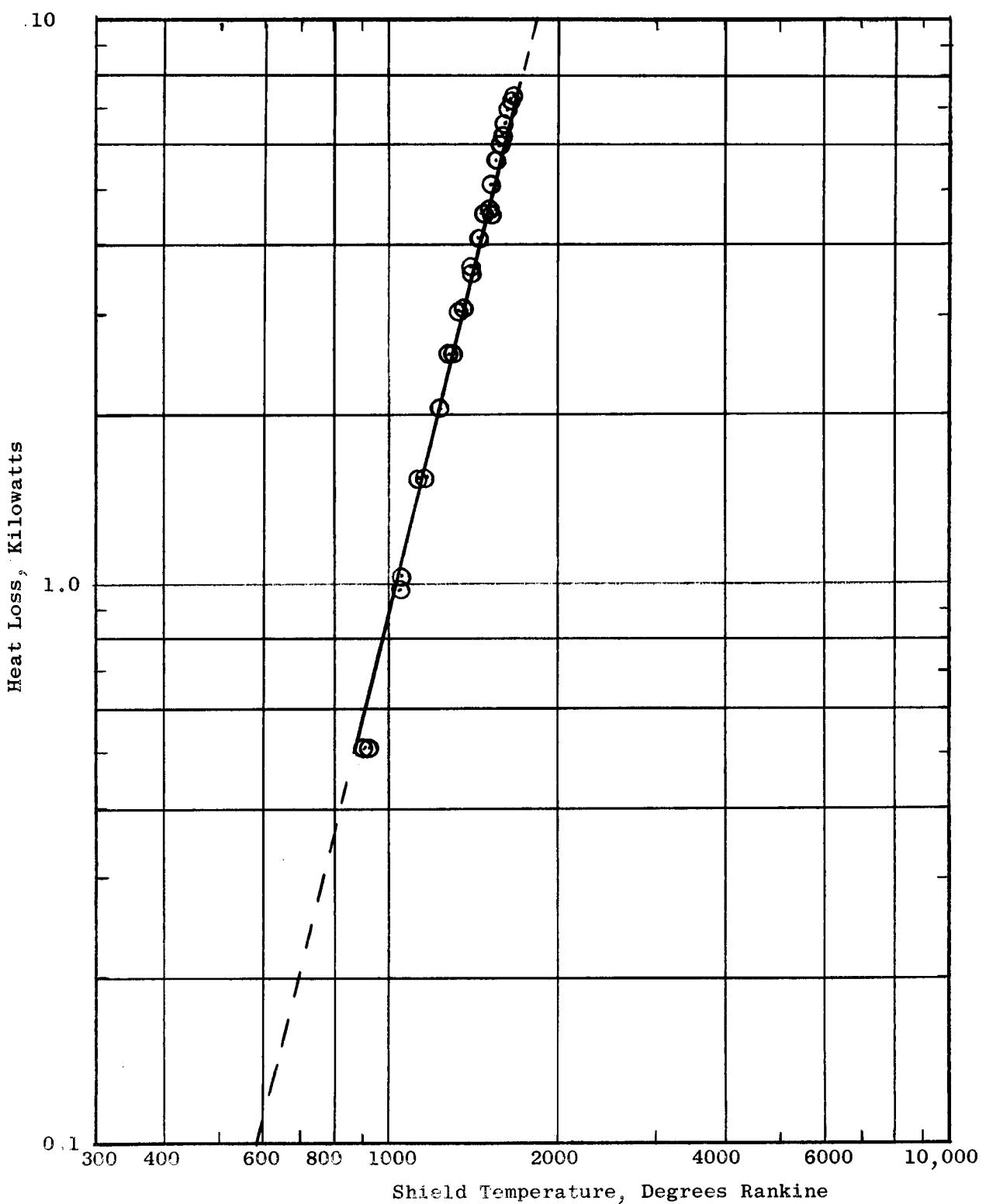


Figure 17 . Boiler Heat Loss in the 100 KW Facility

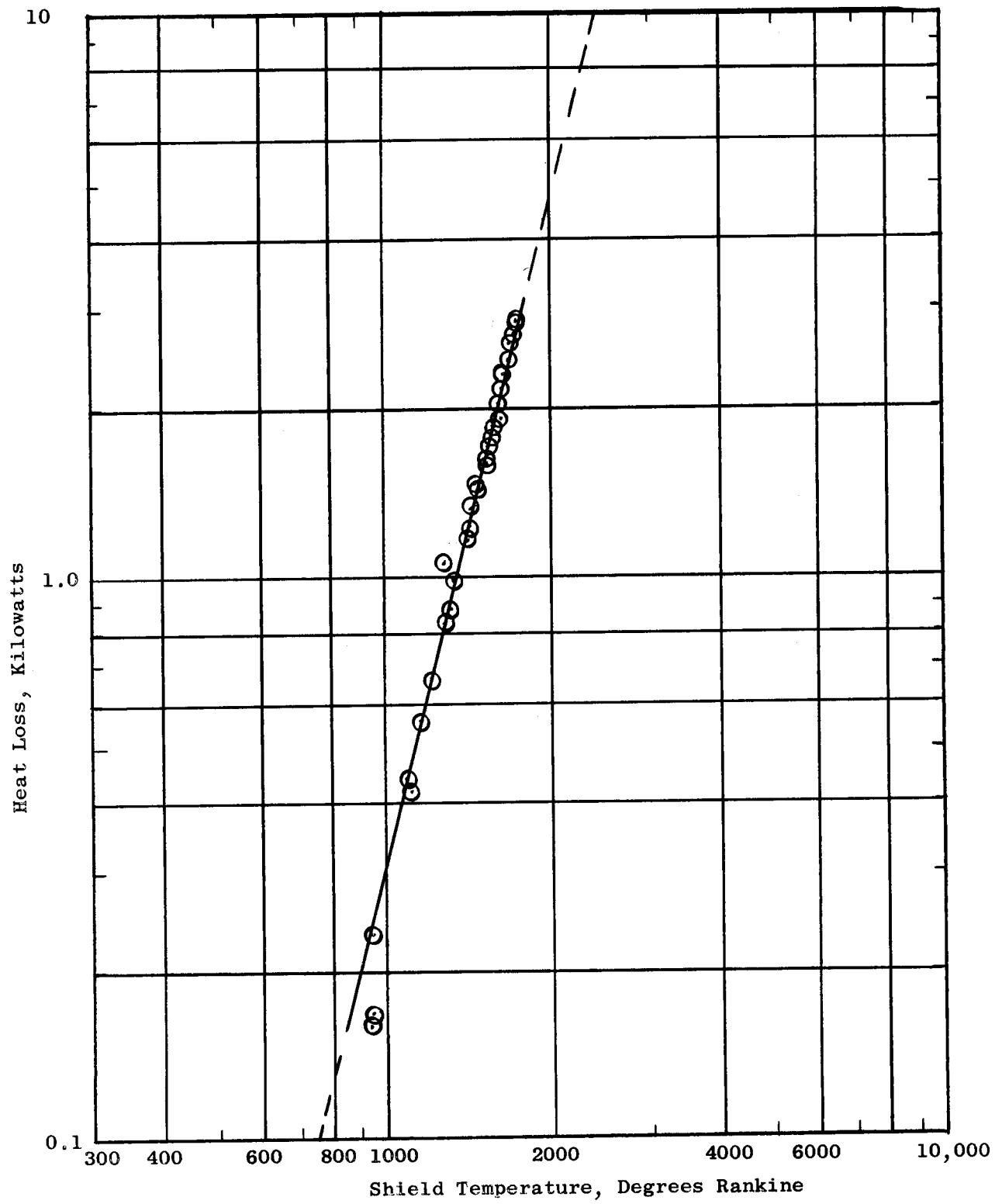


Figure 18. Preheater Heat Loss in 100 KW Facility

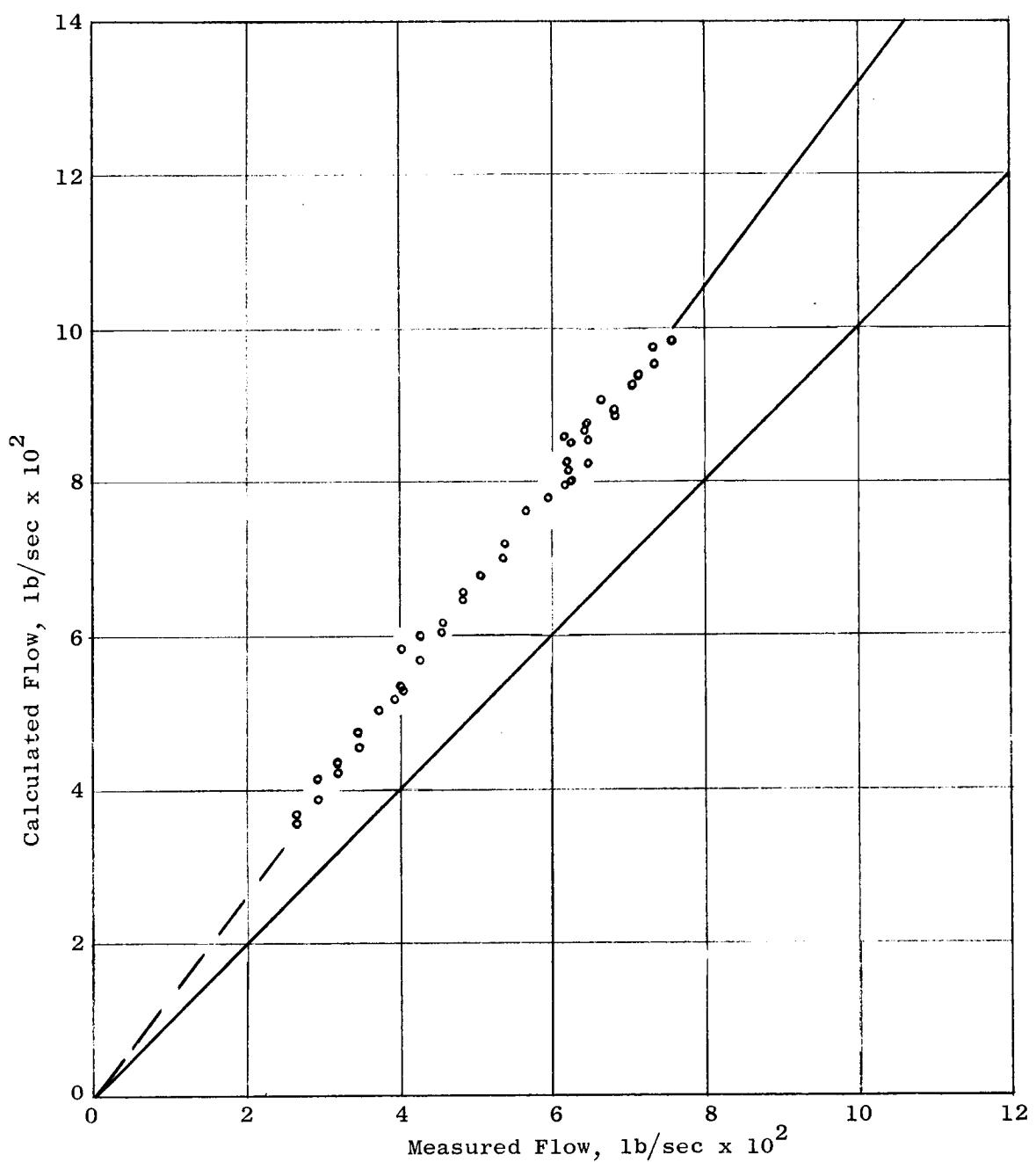


Figure 19. 100 KW Facility Flowmeter Calibration.

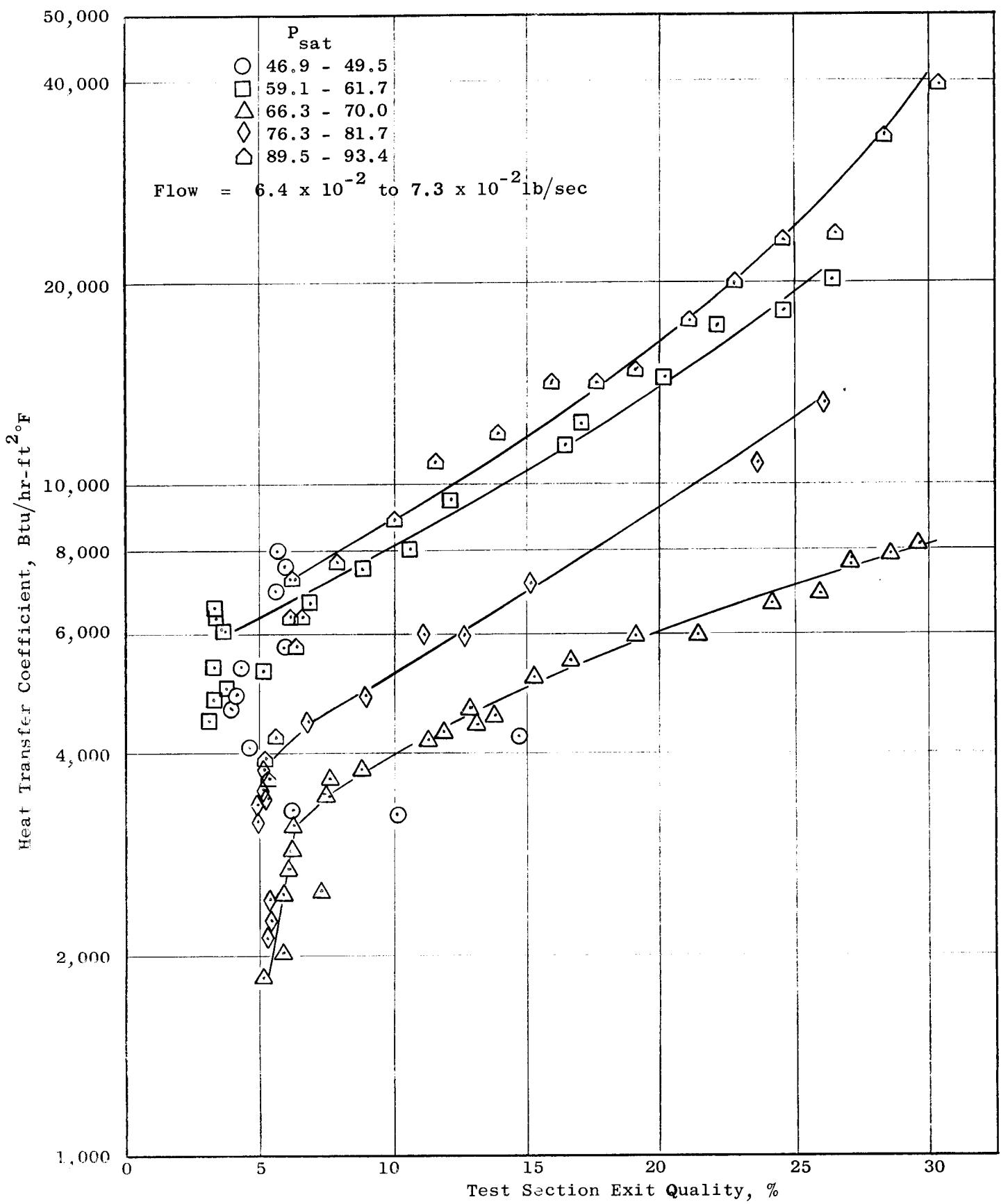


Figure 20. 100 KW Boiling Potassium Data

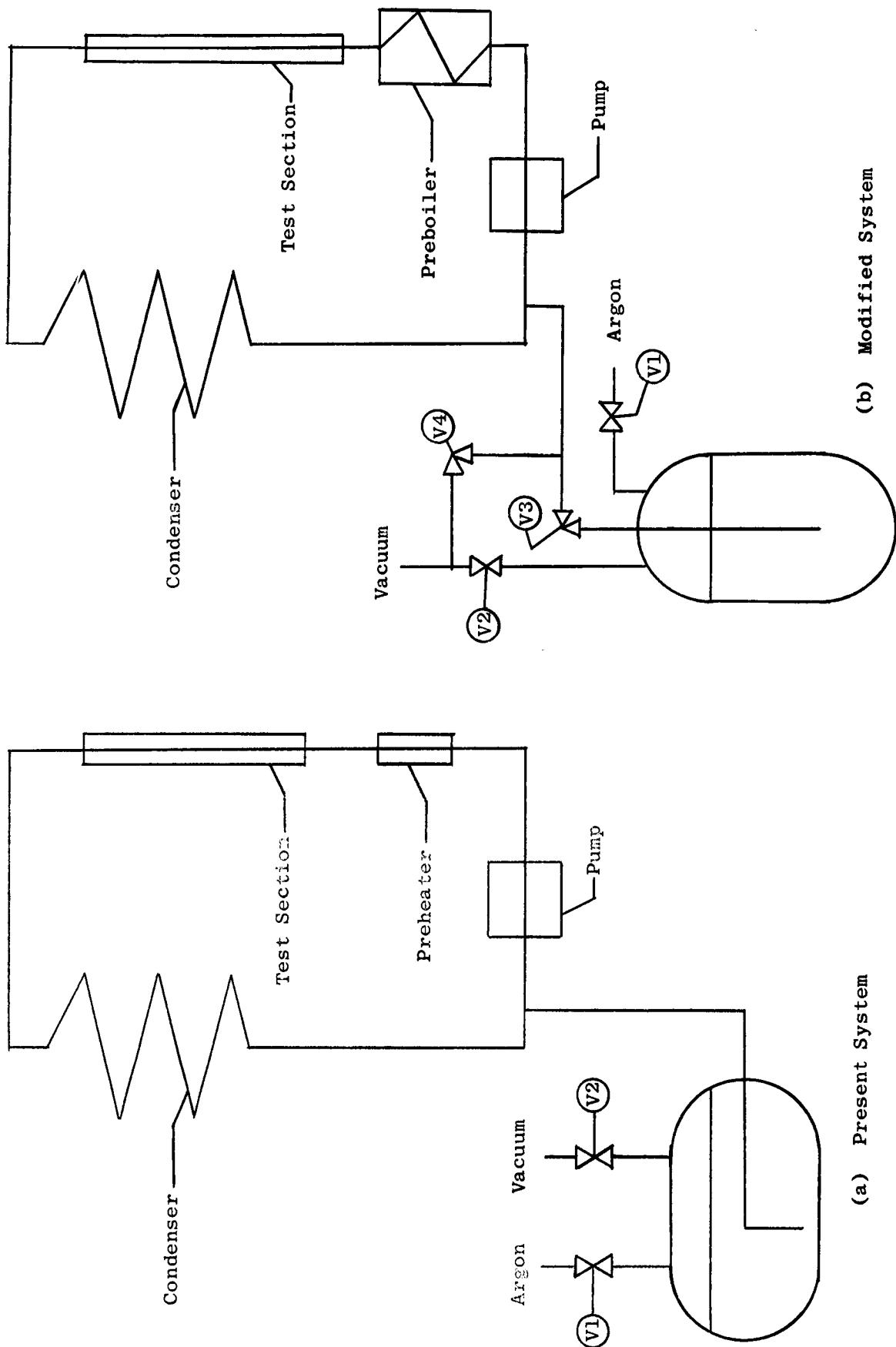


Figure 21. Schematic Representation of Present and Modified 100 KW Loop.

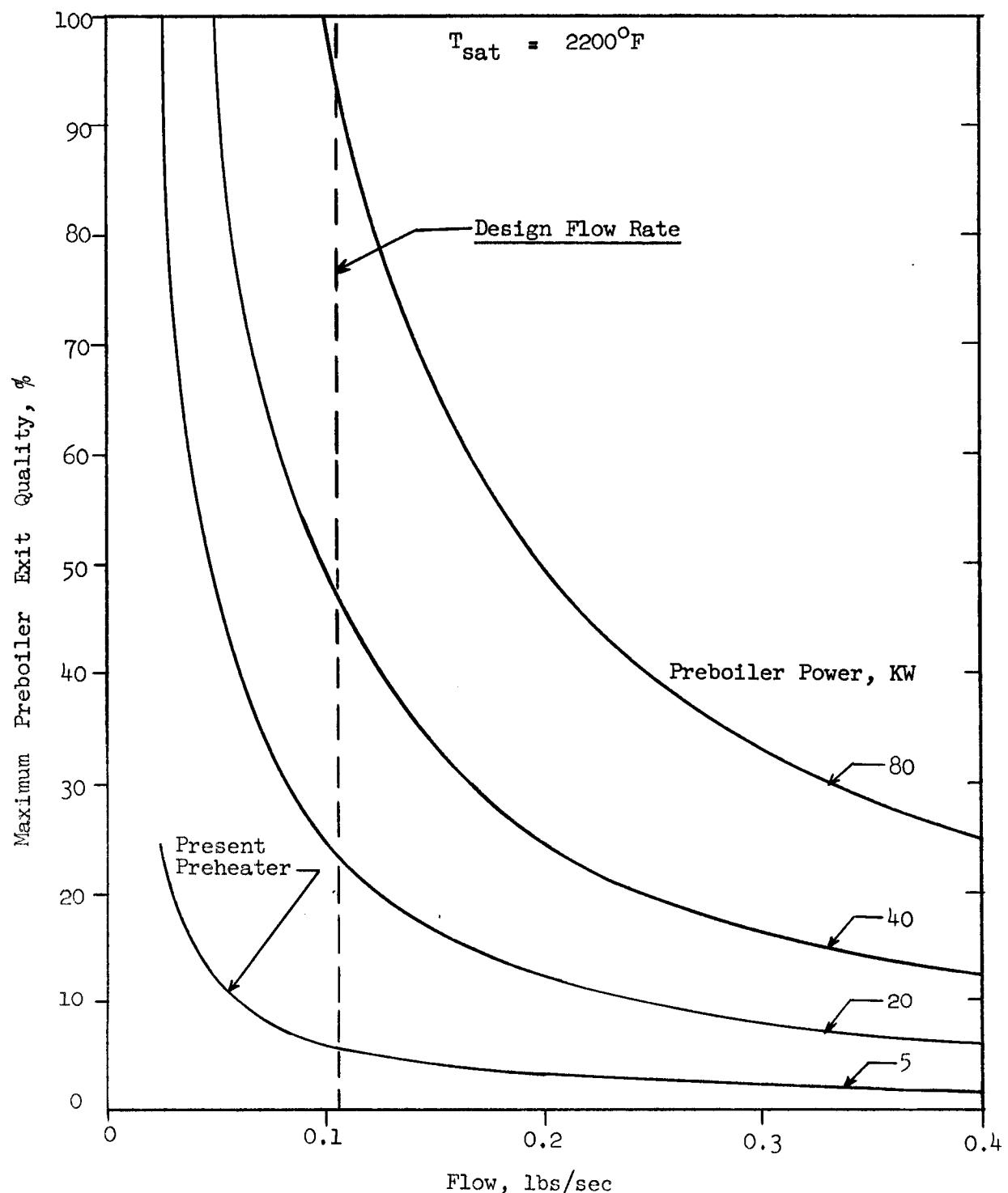


Figure 22. Preboiler Exit Quality as a Function of Flow

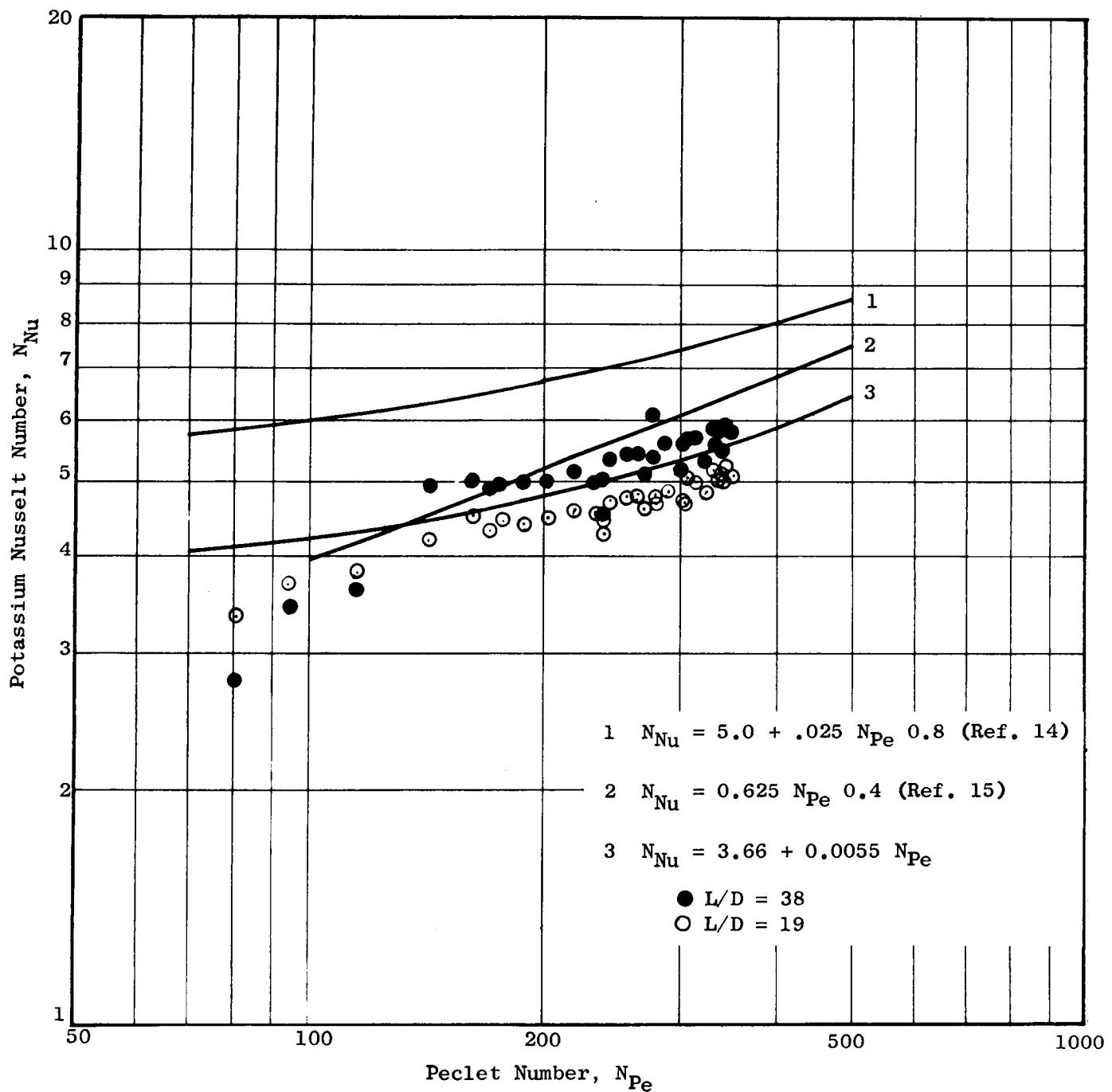


Figure 23. Liquid Heat Transfer Results from the 50 KW Facility.

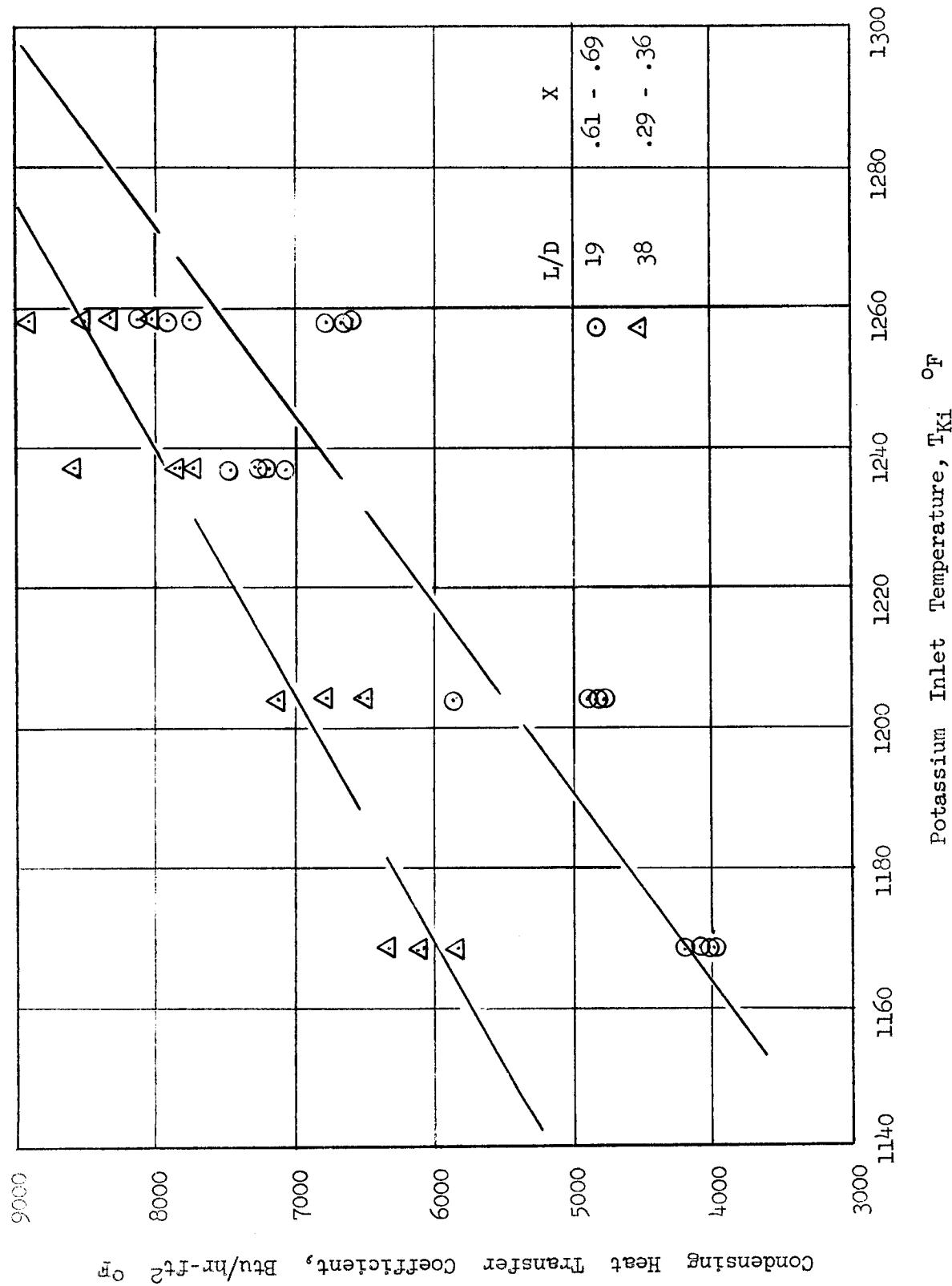


Figure 24. Condensing Results from the 50 KW Facility:  
a) Condensing Heat Transfer Data.

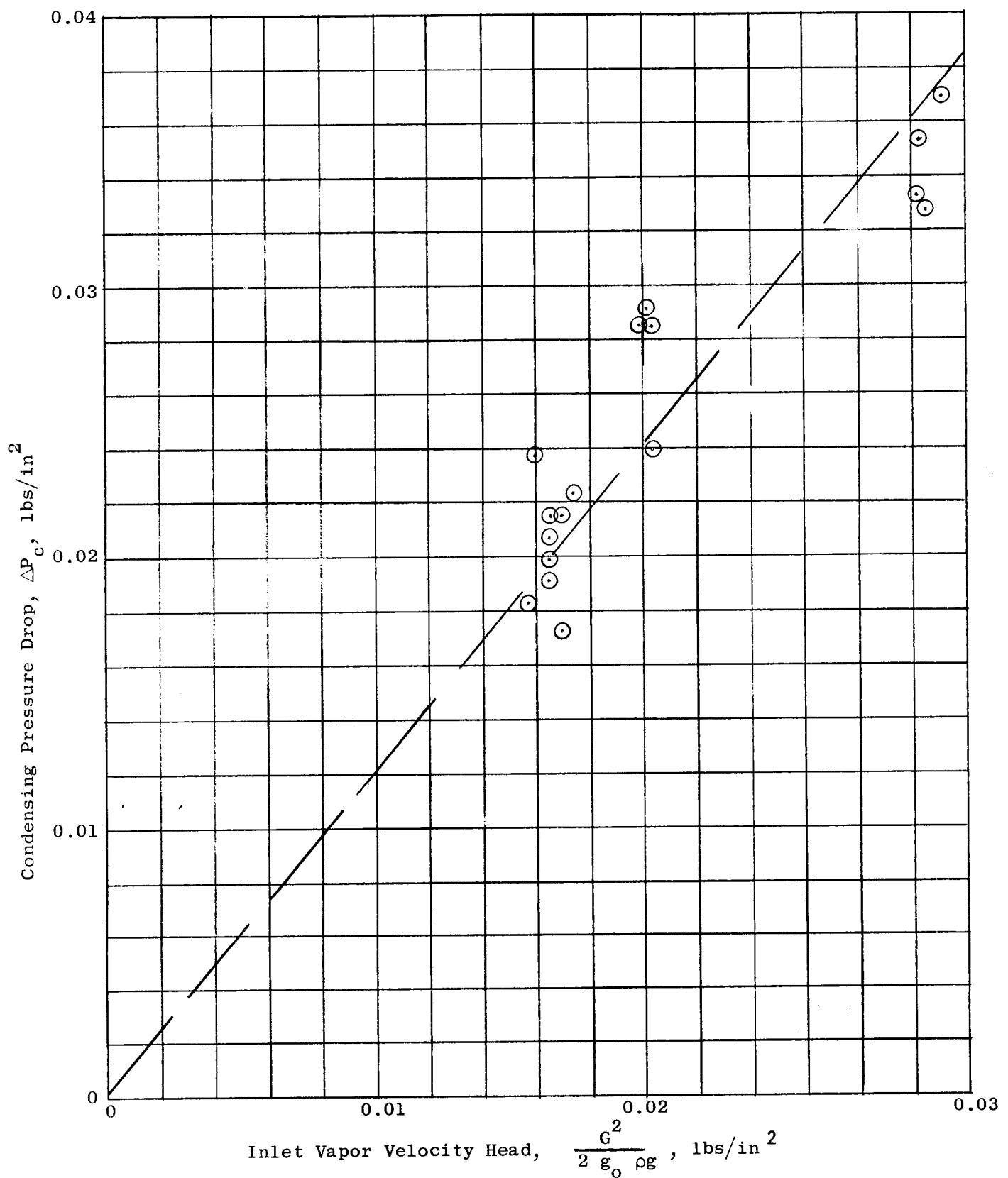


Figure 24. Condensing Results from the 50 KW Facility:  
 b) Condensing Pressure Drop Data.

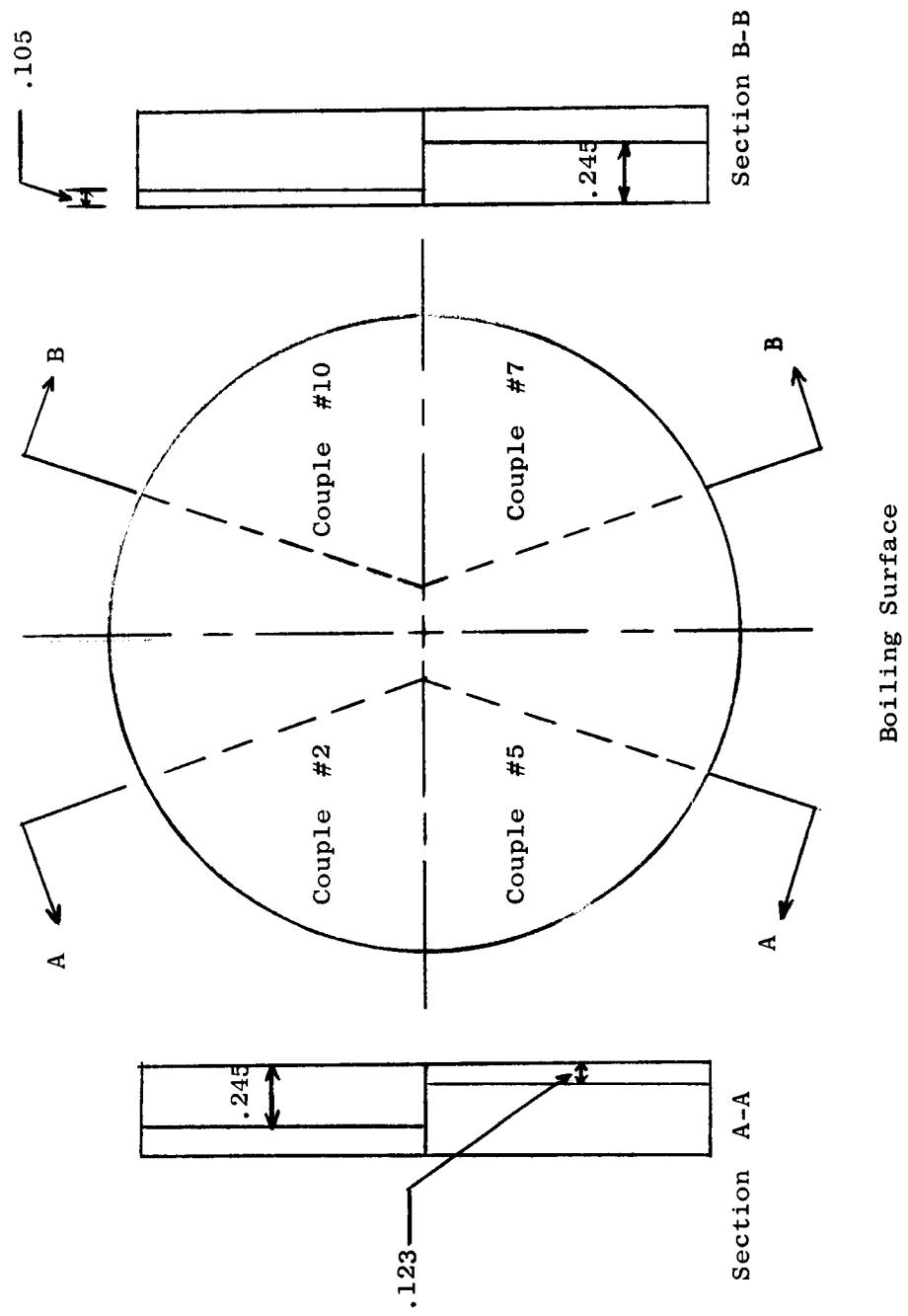


Figure 25. Location of Pool Boiler Thermocouples.

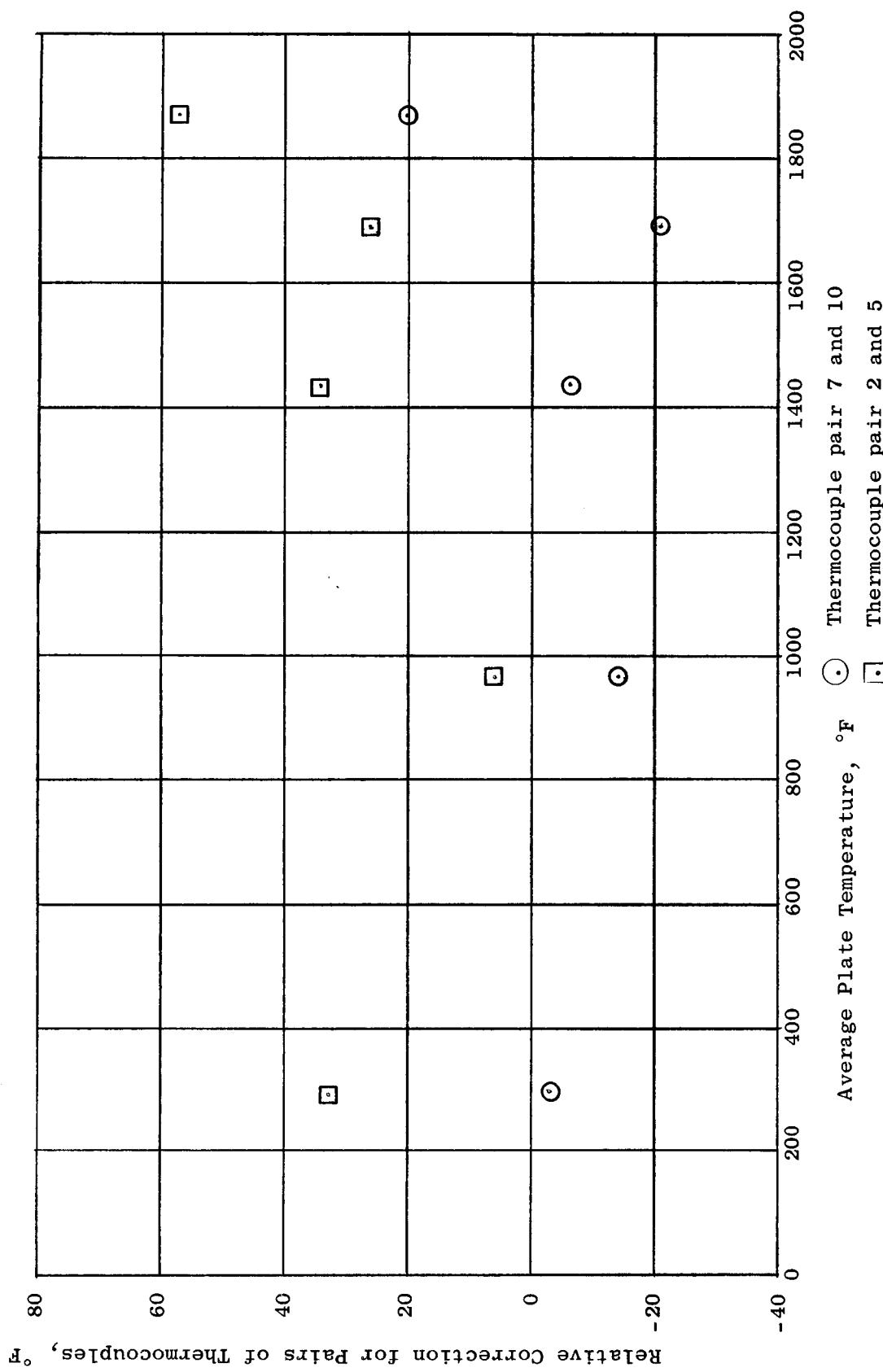


Figure 26 . Correction for Thermocouple Pairs vs. Average Plate Temperature for the Pool Boiler.

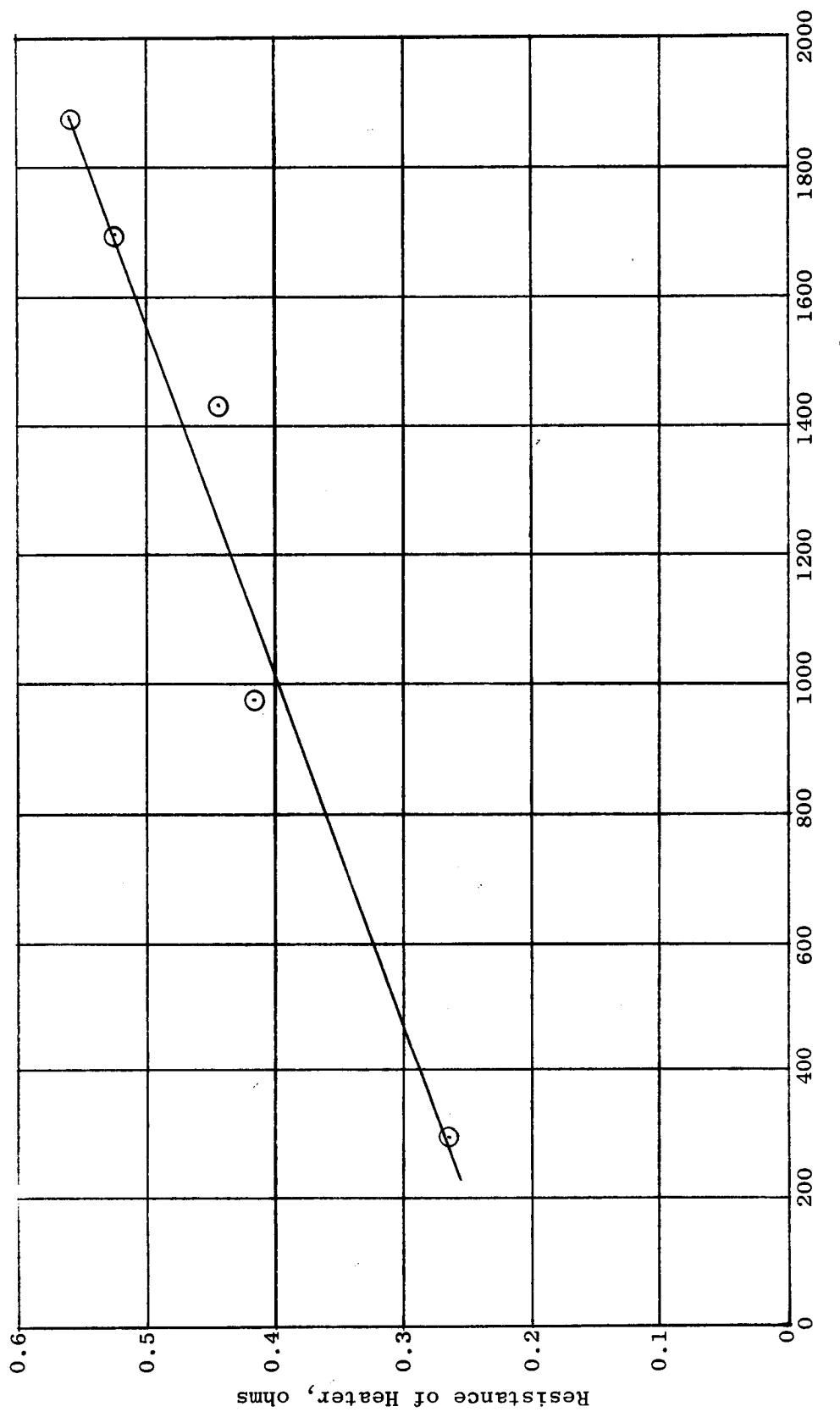


Figure 27. Electrical Resistance of the Sprayed Molybdenum Heater as a Function of Average Plate Temperature for the Pool Boiler.

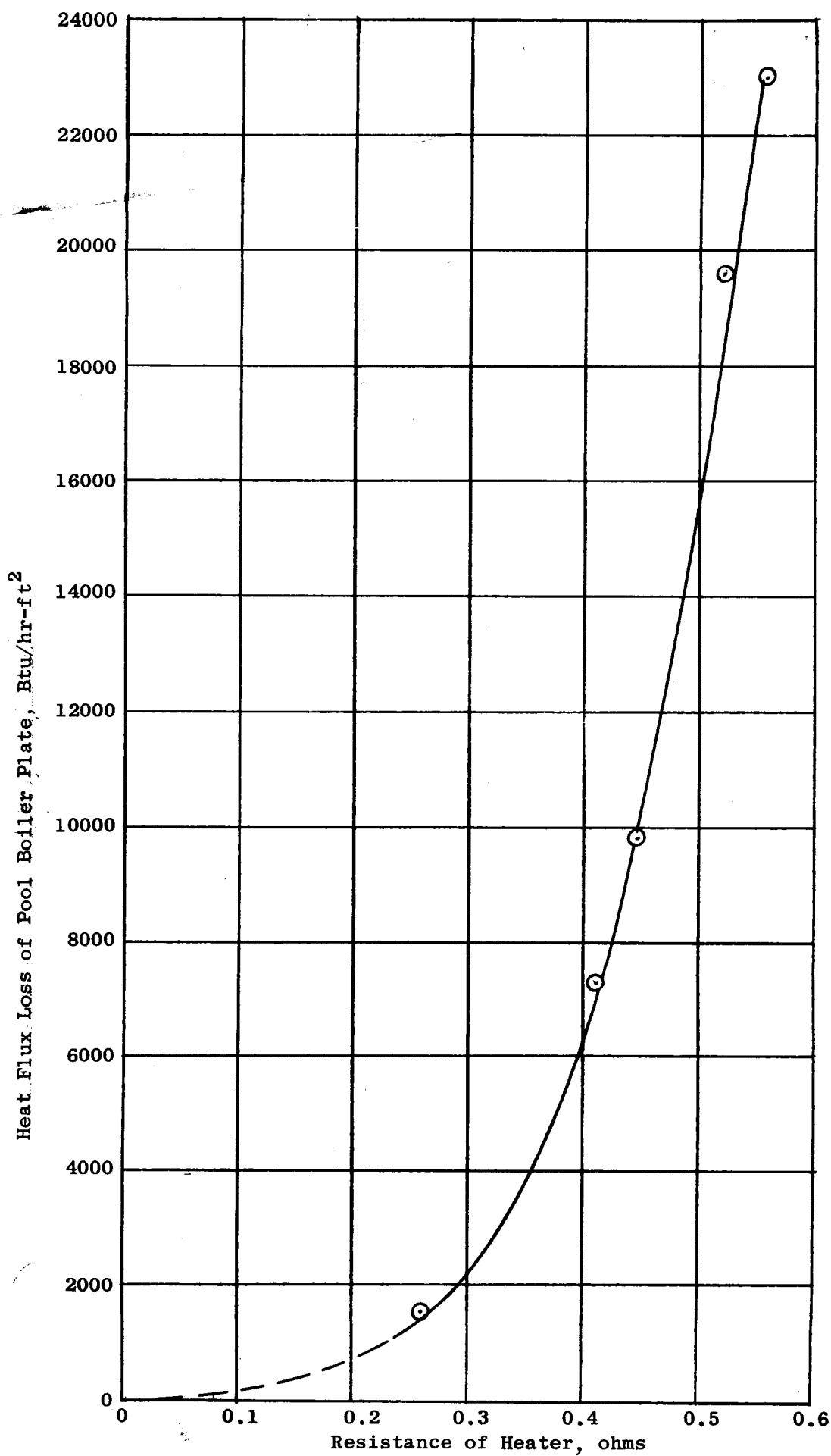


Figure 28. Heat Flux Loss as a Function of Heater Resistance for the Pool Boiler.  
-155-

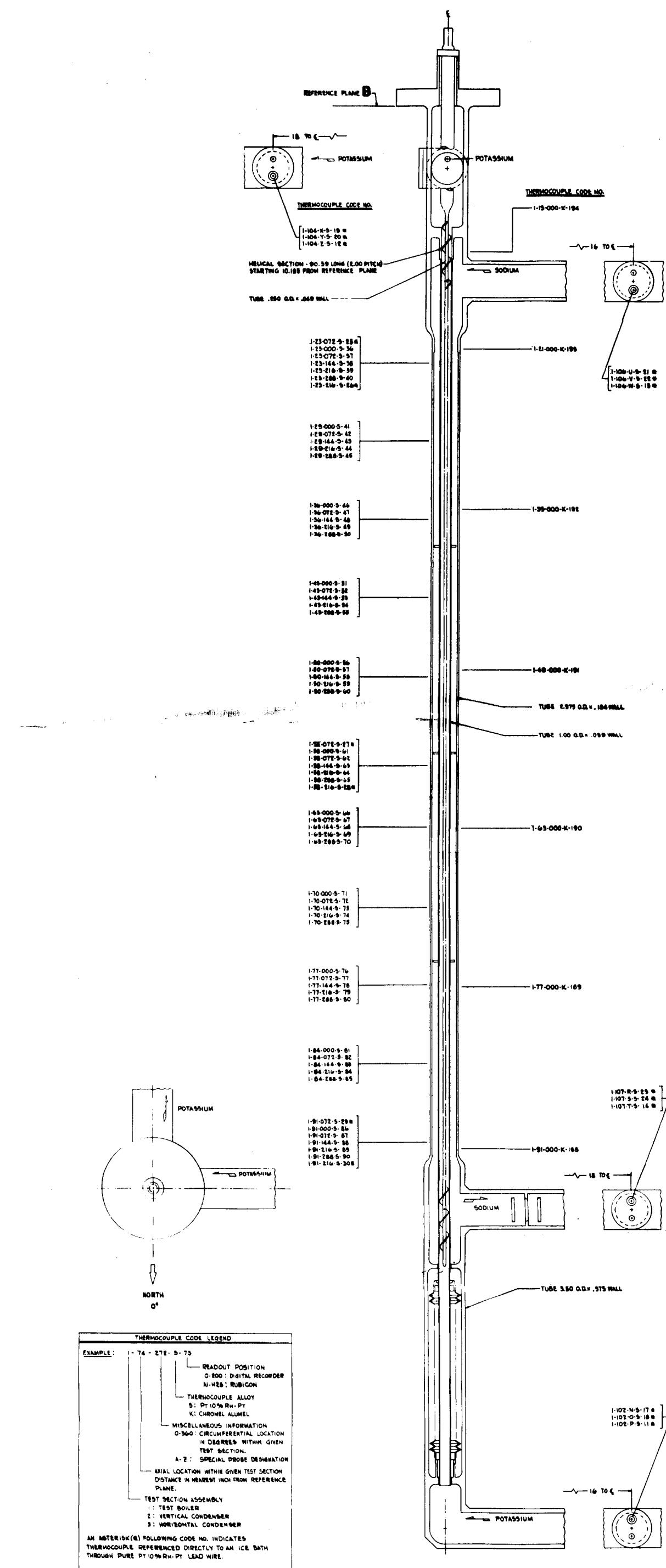


Figure 29. 300 KW Boiler Thermocouple Locations.

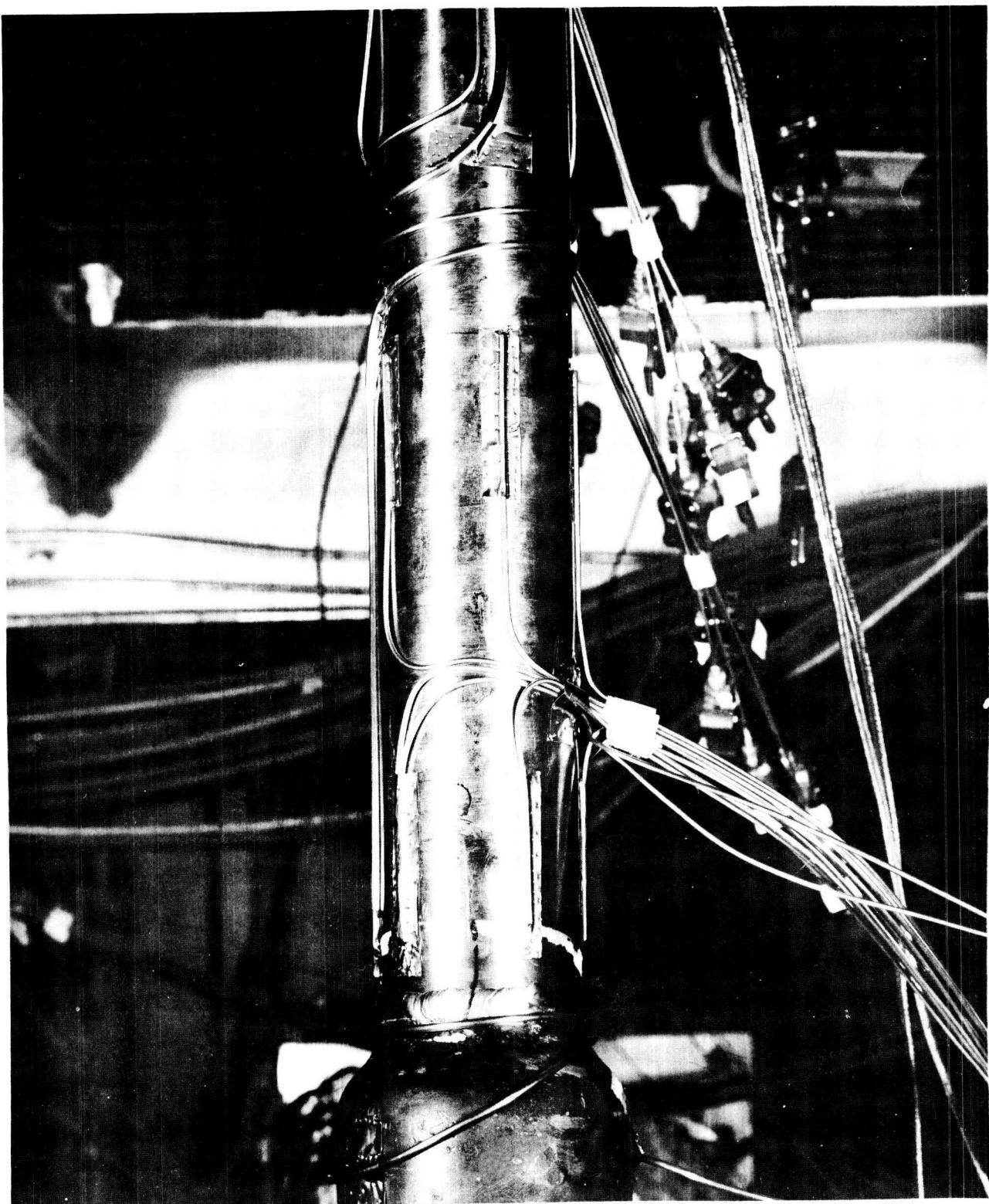


Figure 30. 300 KW Boiler Shell Thermocouple Attachment - (.062 inch O.D. L605 Sheathed Pt10%Rh - Pt Wire with Capped Ungrounded Junctions).

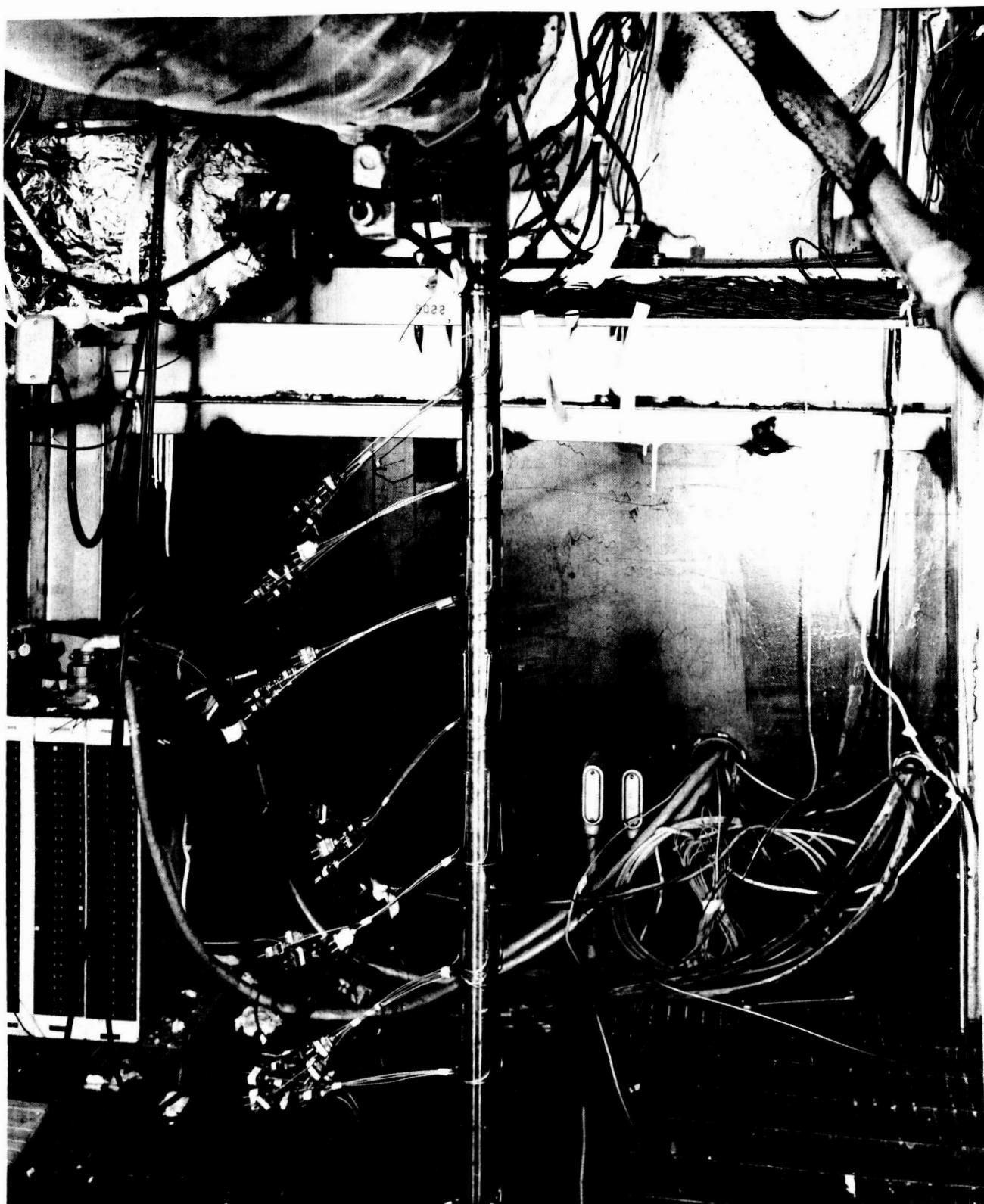


Figure 31. 300 KW Boiler Shell Thermocouple Locations—Overall.

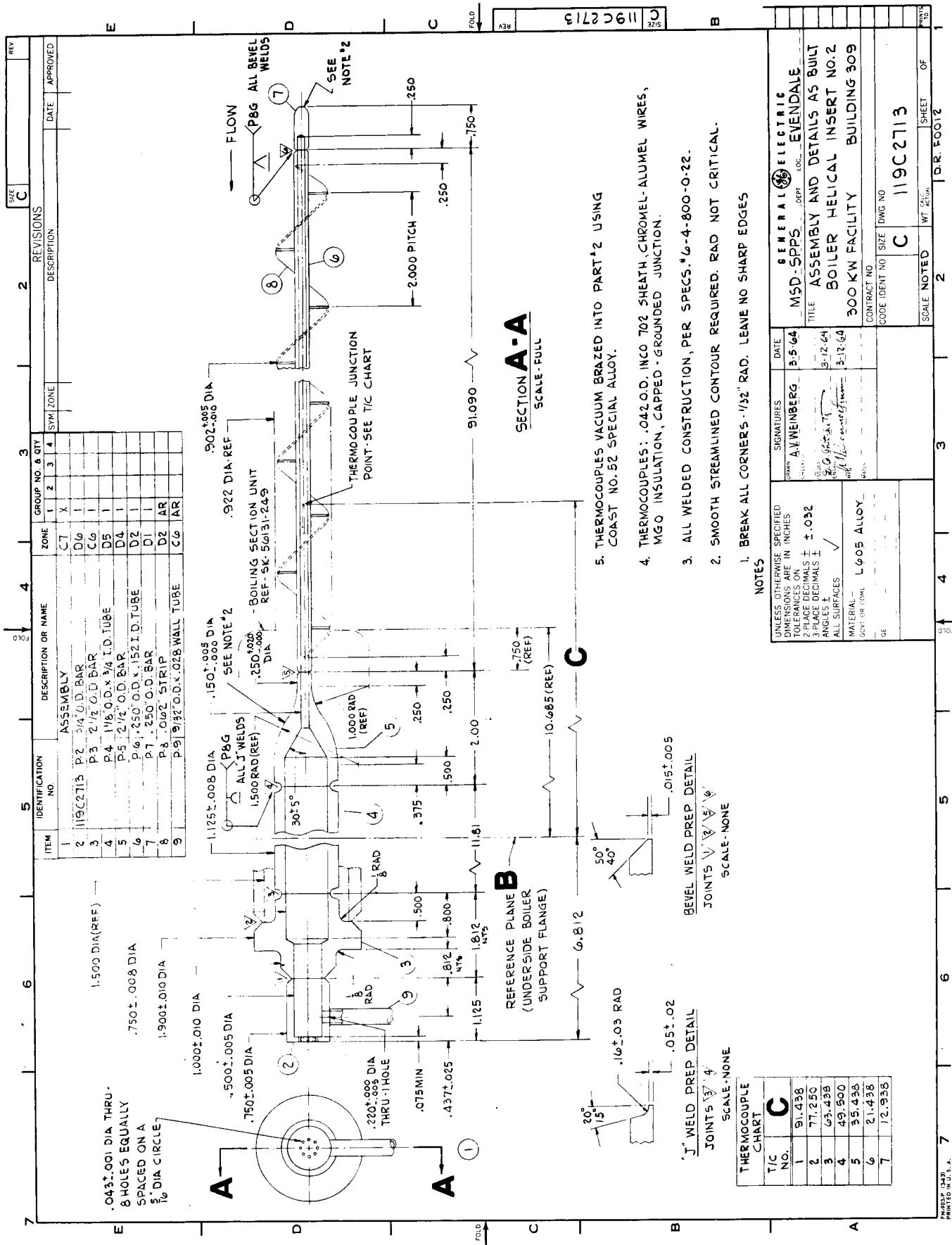




Figure 33. 300 KW Gas Fired Heater Tube Wall Thermocouple. (This is One of 4 Installed During Manufacture of the Heater).



Figure 34. L-605 Alloy Helical Insert Support Tube Following Removal from the 300 KW Loop. The Short Length of 0.25-Inch Diameter Tube which Failed was Deformed Around and Into the End of the Support Tube.  
Mag. 8x

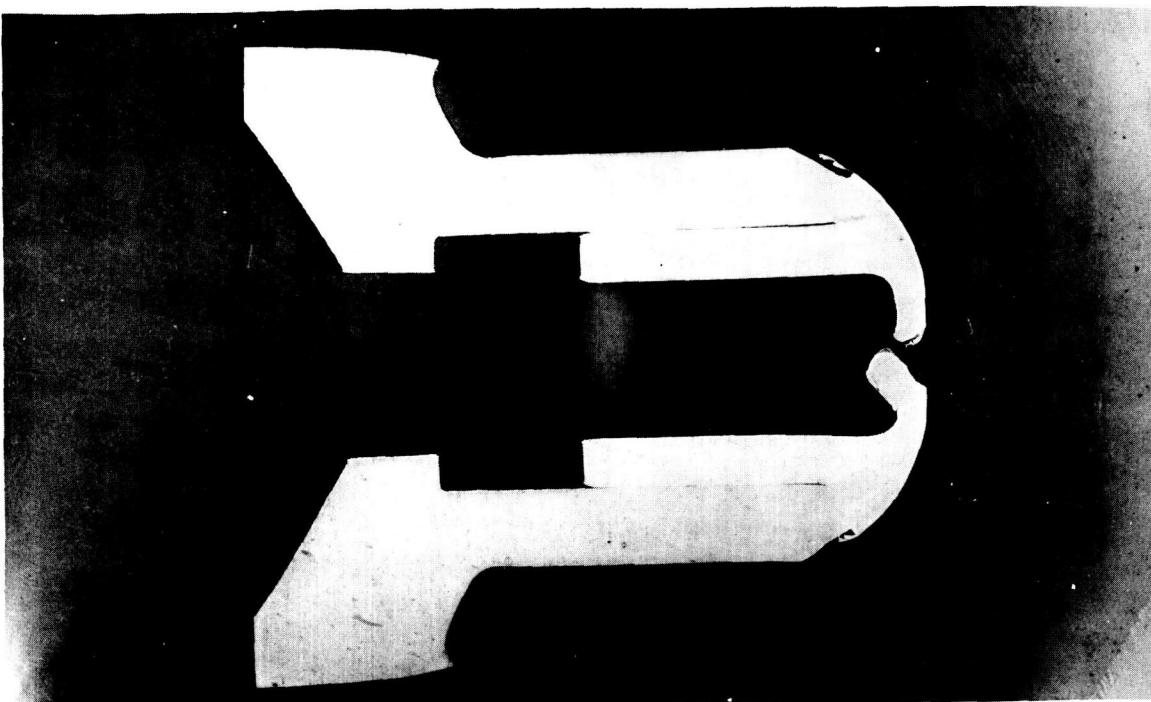


Figure 35. Cross Section of L-605 Alloy Insert Support Tube Shown in Figure 34. Note that the Weld has Remained Intact, Although Severe Deformation of the Short Length of Failed Tube has Occurred.  
Mag. 6x



Figure 36. Outer Surface of Mo-0.5Ti Alloy Boiler Test Section Tube  
Following Exposure in 300 KW Loop. Note the Two Phase  
Metallic Surface Layer which was Found to Contain  
Primarily Co, Ni, Cr and Fe.  
Unetched. Mag. 1000x

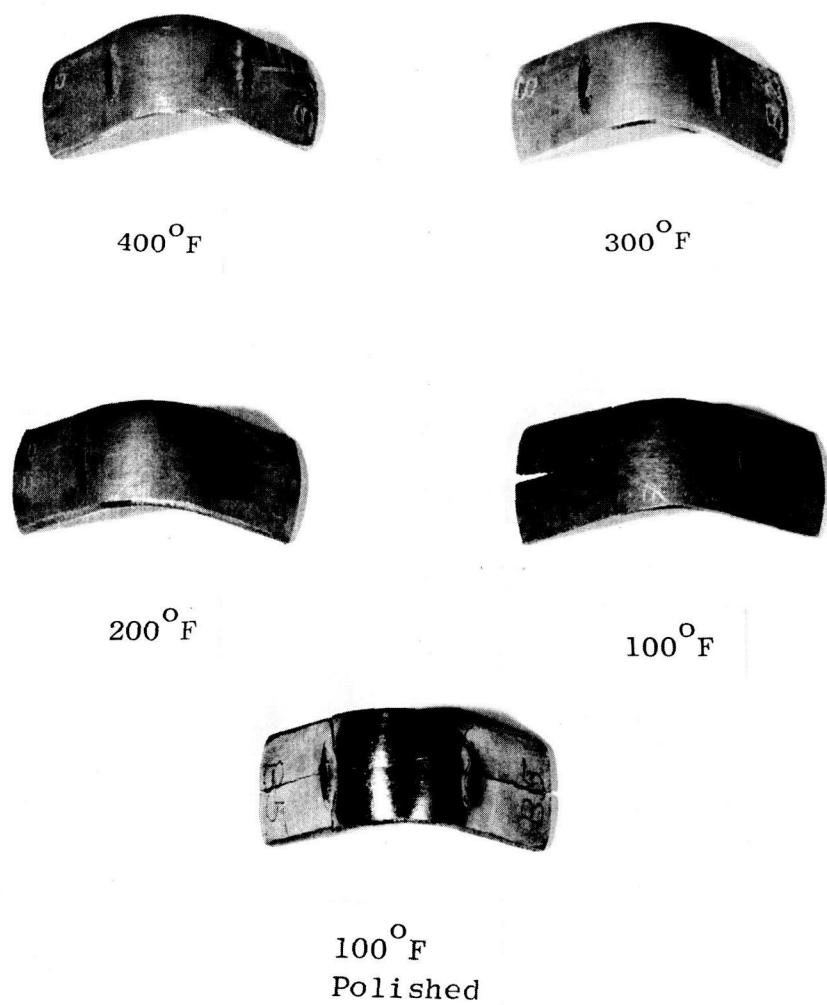


Figure 37. Transverse Bend Test Specimens of Mo-0.5Ti Alloy Tube Following Exposure in 300 KW Loop. Extraneous Failures at 100°F were Caused by Restraint Introduced by the Bending Die.

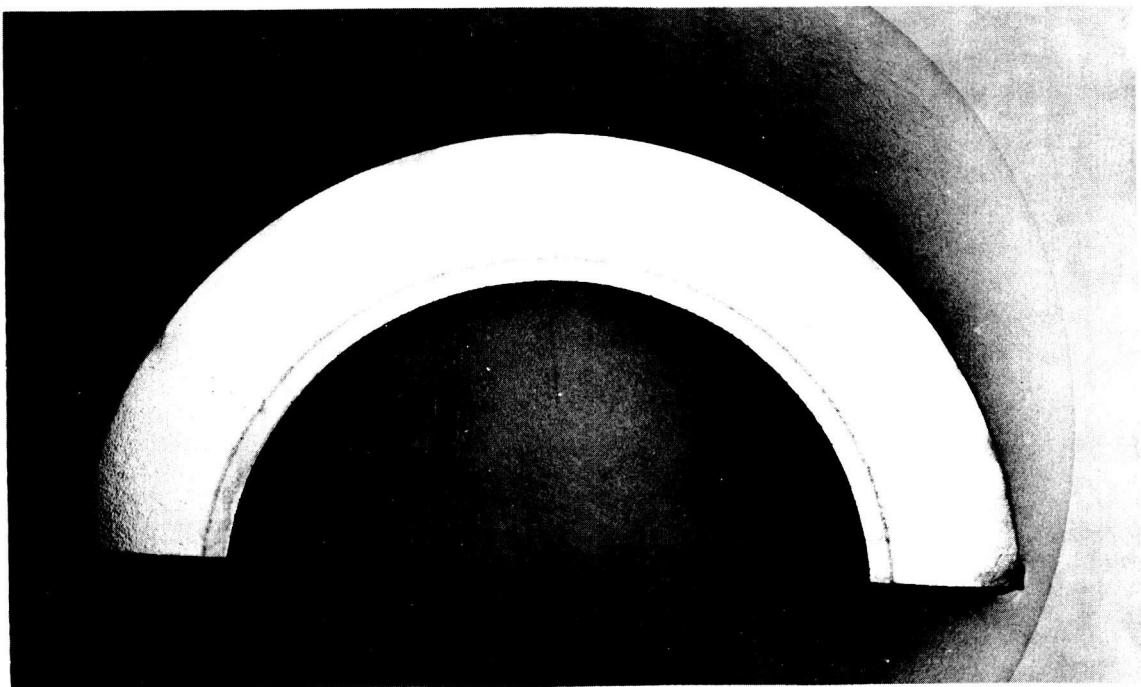
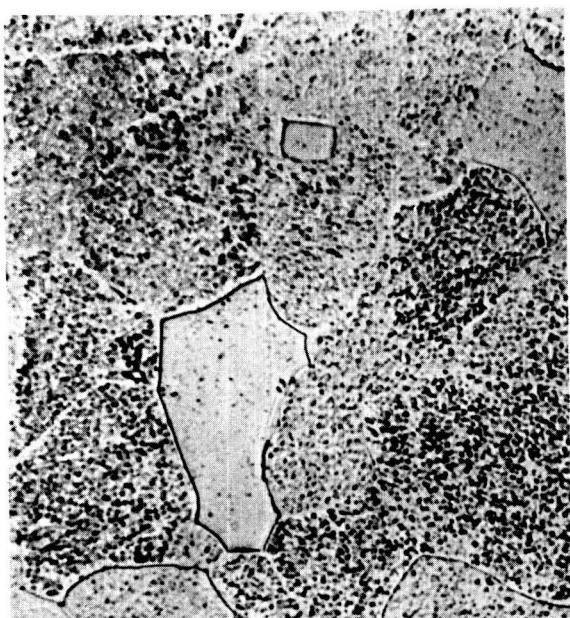


Figure 38. Cross Section of 3/4-Inch Schedule 80 Cb-1Zr Alloy Pipe from Boiler Exit of 100 KW Loop. Note the Oxygen-Contaminated 0.024-Inch Thick Band on Inside of Pipe Wall.  
Etchant: 20HF-20HNO<sub>3</sub>-60H<sub>2</sub>O (Volume per cent)



(a) K1526



(b) K1267

Figure 39. Photomicrographs Typical of the Oxygen-Contaminated Region, (a), and the Uncontaminated Region, (b), Shown in Figure 38. Note the Extensive  $ZrO_2$  precipitation in Region (a) and the Lack of Same in Region (b).  
Etchant:  $20HF-20HNO_3-60H_2O$  (Volume per cent)  
Mag. 1000x

APPENDIX A

300 KW Data

Table A-1  
Column Headings

Some of the temperatures reported were derived from thermocouples with cold junctions in an ice bath, while others were derived from thermocouples with cold junctions at a CATS block. The former temperatures are identified by the subscript (I) as in POT-I.

<u>Col. No.</u>	<u>Title</u>	<u>Description</u>
202	Date	12.263 - 12/26/63
203	Time	2335 - Navy time
205	PFMST	Primary flowmeter stream temperature, °F
207	PFMT	Primary flowmeter magnet temperature, °F
209	SFMST	Secondary flowmeter stream temperature, °F
211	SFMMT	Secondary flowmeter magnet temperature, °F
215	PFLO	Primary flowrate, lb/sec.
219	SFLO	Secondary flowrate, lb/sec.
230, 244, 252	PIT	Primary inlet temperature, °F
259, 267, 275	POT	Primary outlet temperature, °F
314 - 384	GSBW	Grounded platinum-platinum 10% rhodium boiler outer wall thermocouple temp., °F
392 - 424	USBW	Ungrounded platinum-platinum 10% rhodium boiler outer wall thermocouple temp., °F
475, 477, 479	SIT	Secondary inlet temperature, °F
480, 482, 484	SOT	Secondary outlet temperature, °F
486 - 498	BI	Boiler insert thermocouple temperature, °F

<u>Col. No.</u>	<u>Title</u>	<u>Description</u>
502	BIP	Pressure at boiler inlet, psia
505	BOP	Pressure at boiler outlet, psia
506	DP-B	Pressure drop across boiler tube, psi
507	TSAT-I	Saturation temperature at boiler inlet pressure, °F
508	DTSC	Subcooling of potassium at entrance to boiler, °F
512	QSC	Heat necessary to raise the potassium temperature from SIT to TSAT-I, Btu/sec.
521	QL	Boiler heat losses, Btu/sec.
526	QPRI	Net heat transferred from primary stream in boiler, Btu/sec.
530	QFLUX	Average heat flux in boiler based upon the inner area, Btu/(hr-ft <sup>2</sup> )
537	QUAL-B	Vapor quality, dimensionless
538	MFV-B	Mass flowrate of vapor leaving boiler, lb/sec.
542	VVEL-B	Superficial vapor velocity at boiler exit, ft/sec.
543	DTO-SO	Temperature difference between primary fluid and secondary fluid at secondary outlet, °F
544	DTO-SI	Temperature difference between primary fluid and secondary fluid at secondary inlet, °F
548	DTLM-0	Logarithmic average of DTO-SO and DTO-SI.
549	UO	Overall heat transfer coefficient of boiler tube, Btu/ft <sup>2</sup> -°F-hr
600, 603, 605	VCIT	Vertical condenser inlet temperature, °F

<u>Col.</u>	<u>Title</u>	<u>Description</u>
No.		
606, 608, 610	VCOT	Vertical condenser outlet temperature, °F
611	SP VCO	Vapor pressure of potassium at VCOT-I, psia
613	DP-VC	Pressure drop across vertical condenser, psi
614, 616, 618	HCOT	Horizontal condenser outlet temperature, °F
622, 624	HCAI	Horizontal condenser air inlet temp., °F
626	HCAO-H	Horizontal condenser air outlet, temp., °F
628	HCO-T	Horizontal condenser air temperature at inlet orifice, °F.
630 - 658	HA	Horizontal condenser air annulus temp., °F
660	HCOSTU	Horizontal condenser outer skin temperature upstream, °F
662	HCOSTD	Horizontal condenser outer skin temperature downstream, °F
672	WA	Mass flow rate of air in horizontal condenser, lb/sec
680	QA	Heat removed in horizontal condenser, Btu/sec.
694	DTLMHC	Logarithmic average of temperature difference across horizontal condenser
697	UO HC	Overall heat transfer coefficient of horizontal condenser, Btu/ft <sup>2</sup> -°F-hr

Table A-2

## 300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	202	203	205	207	209	211
	DATE	TIME	PFMST	PFMMT	SFMST	SFMMT
1	1.2263+01	2.3350+03	1.3855+03	1.6697+02	1.2034+03	1.3231+02
2	1.2273+01	1.1200+02	1.4158+03	1.6912+02	1.2274+03	1.3279+02
3	1.2273+01	3.5900+02	1.5100+03	1.7928+02	1.2562+03	1.3728+02
4	1.2273+01	6.1500+02	1.6274+03	1.8882+02	1.3174+03	1.3834+02
5	1.2273+01	7.2500+02	1.6487+03	1.9291+02	1.2964+03	1.3891+02
6	1.2273+01	1.0000+03	1.6869+03	2.0162+02	1.3676+03	1.4278+02
7	1.2273+01	1.1150+03	1.6941+03	2.0435+02	1.3981+03	1.4595+02
8	1.2273+01	1.5300+03	1.8218+03	2.2265+02	1.6380+03	1.6639+02
9	1.2273+01	1.6300+03	1.8089+03	2.2736+02	1.6080+03	1.6878+02
10	1.2273+01	1.7300+03	1.8118+03	2.2868+02	1.5747+03	1.6794+02
11	1.2273+01	1.8450+03	1.8052+03	2.2798+02	1.4957+03	1.6210+02
12	1.2273+01	1.9500+03	1.7982+03	2.2679+02	1.4351+03	1.5695+02
13	1.2273+01	2.1400+03	1.7949+03	2.2551+02	1.4141+03	1.5215+02
14	1.2273+01	2.2300+03	1.7962+03	2.2410+02	1.3442+03	1.4766+02
15	1.2273+01	2.3130+03	1.7741+03	2.2507+02	1.2106+03	1.4335+02
16	1.2283+01	5.0000+00	1.7986+03	2.2806+02	1.2252+03	1.4018+02
17	1.2283+01	1.1000+02	1.7775+03	2.2670+02	1.2096+03	1.3706+02
18	1.2283+01	2.3000+02	1.7984+03	2.2217+02	1.2343+03	1.3297+02
19	1.2283+01	4.4000+02	1.7941+03	2.1737+02	1.2146+03	1.2773+02
20	1.2283+01	7.0000+02	1.7956+03	2.1341+02	1.1827+03	1.2289+02
21	1.2283+01	8.3000+02	1.7936+03	2.1196+02	1.0962+03	1.1924+02
22	1.2283+01	9.4500+02	1.7882+03	2.1055+02	1.0638+03	1.1695+02
23	1.2283+01	1.1150+03	1.7834+03	2.1108+02	1.0134+03	1.1616+02
24	1.2283+01	1.2450+03	1.7914+03	2.1684+02	8.8656+02	1.1400+02
25	1.2283+01	1.5250+03	1.8265+03	2.1962+02	8.4256+02	1.1458+02
26	1.2283+01	2.1400+03	1.6195+03	1.8666+02	1.0514+03	1.1066+02
27	1.2283+01	2.2350+03	1.6225+03	1.8319+02	1.0587+03	1.0925+02
28	1.2283+01	2.3350+03	1.6301+03	1.8205+02	1.1322+03	1.1026+02
29	1.2293+01	3.5000+01	1.6479+03	1.7378+02	1.1567+03	1.1260+02
30	1.2293+01	1.3500+02	1.6554+03	1.8310+02	1.1757+03	1.1444+02
31	1.2293+01	2.3500+02	1.6821+03	1.8449+02	1.2142+03	1.1590+02
32	1.2293+01	3.3500+02	1.7164+03	1.8780+02	1.2212+03	1.1840+02
33	1.2293+01	4.3500+02	1.7397+03	1.9159+02	1.3013+03	1.2087+02
34	1.2293+01	5.4500+02	1.7261+03	1.9533+02	1.3313+03	1.2461+02
35	1.2293+01	6.3500+00	1.7466+03	1.9647+02	1.3130+03	1.2619+02
36	1.2293+01	7.3000+02	1.7774+03	1.9841+02	1.2663+03	1.2593+02
37	1.2293+01	1.0000+03	1.8083+03	2.0571+02	1.3589+03	1.3147+02
38	1.2293+01	1.1150+03	1.7914+03	2.0853+02	1.3607+03	1.3341+02
39	1.2293+01	1.2150+03	1.7800+03	2.1200+02	1.3440+03	1.3644+02
40	1.2293+01	1.3150+03	1.7601+03	2.0985+02	1.3190+03	1.3517+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	215	219	230	244	252	259
	PFL0	SFLO	PIT-I	PIT	PIT	POT-I
1	7.9761+00	1.8974+00	1.4008+03	1.4062+03	1.4060+03	1.3836+03
2	7.0556+00	1.8549+00	1.4322+03	1.4372+03	1.4371+03	1.4145+03
3	7.3991+00	1.8128+00	1.5286+03	1.5322+03	1.5322+03	1.5060+03
4	1.1289+01	1.5618+00	1.6460+03	1.6470+03	1.6471+03	1.6212+03
5	1.1217+01	1.5040+00	1.6711+03	1.6718+03	1.6721+03	1.6421+03
6	1.1045+01	1.3532+00	1.7103+03	1.7105+03	1.7105+03	1.6796+03
7	1.1039+01	1.3430+00	1.7184+03	1.7169+03	1.7170+03	1.6887+03
8	1.0725+01	1.3211+00	1.8376+03	1.8330+03	1.8331+03	1.8132+03
9	1.0744+01	1.3131+00	1.8270+03	1.8226+03	1.8227+03	1.8008+03
10	1.0783+01	1.2358+00	1.8331+03	1.8286+03	1.8287+03	1.8026+03
11	1.0803+01	1.1364+00	1.8339+03	1.8295+03	1.8296+03	1.7972+03
12	1.0850+01	1.0734+00	1.8309+03	1.8262+03	1.8267+03	1.7906+03
13	1.0798+01	1.0689+00	1.8308+03	1.8258+03	1.8264+03	1.7895+03
14	1.0768+01	1.0078+00	1.8353+03	1.8312+03	1.8318+03	1.7890+03
15	1.0736+01	1.0575+00	1.8194+03	1.8180+03	1.8183+03	1.7663+03
16	1.0702+01	9.5571-01	1.8351+03	1.8419+03	1.8425+03	1.7913+03
17	1.0884+01	1.0951+00	1.8233+03	1.8168+03	1.8176+03	1.7705+03
18	1.0805+01	9.5055-01	1.8440+03	1.8383+03	1.8392+03	1.7919+03
19	1.0804+01	8.4082-01	1.8365+03	1.8334+03	1.8335+03	1.7865+03
20	1.0758+01	7.0263-01	1.8395+03	1.8360+03	1.8367+03	1.7877+03
21	1.0976+01	5.6039-01	1.8379+03	1.8329+03	1.8338+03	1.7860+03
22	1.0939+01	4.3962-01	1.8320+03	1.8281+03	1.8279+03	1.7803+03
23	1.0930+01	2.9550-01	1.8270+03	1.8221+03	1.8230+03	1.7764+03
24	1.0860+01	1.5604-01	1.8334+03	1.8301+03	1.8305+03	1.7860+03
25	1.0852+01	1.4778-01	1.8604+03	1.8564+03	1.8563+03	1.8181+03
26	6.9938+00	1.3441-01	1.6561+03	1.6569+03	1.6572+03	1.6165+03
27	6.9898+00	1.4637-01	1.6557+03	1.6566+03	1.6567+03	1.6173+03
28	6.9158+00	1.4752-01	1.6637+03	1.6642+03	1.6643+03	1.6251+03
29	6.8587+00	1.5196-01	1.6814+03	1.6828+03	1.6834+03	1.6414+03
30	6.8512+00	1.4632-01	1.6892+03	1.6900+03	1.6903+03	1.6479+03
31	6.8304+00	1.4703-01	1.7187+03	1.7189+03	1.7192+03	1.6753+03
32	6.7527+00	1.0687-01	1.7540+03	1.7522+03	1.7521+03	1.7095+03
33	6.6934+00	1.7126-01	1.7828+03	1.7822+03	1.7817+03	1.7330+03
34	6.7105+00	1.8847-01	1.7635+03	1.7635+03	1.7631+03	1.7181+03
35	6.6854+00	1.6346-01	1.7893+03	1.7865+03	1.7866+03	1.7409+03
36	6.6411+00	8.1196-02	1.7982+03	1.7965+03	1.7964+03	1.7682+03
37	6.5451+00	2.0581-01	1.8632+03	1.8607+03	1.8605+03	1.7996+03
38	6.5845+00	1.8531-01	1.8440+03	1.8397+03	1.8404+03	1.7841+03
39	6.8104+00	2.0545-01	1.8295+03	1.8263+03	1.8261+03	1.7734+03
40	6.8348+00	2.1286-01	1.8082+03	1.8040+03	1.8041+03	1.7533+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	267	275	314	324	338	352
	POT	POT	GSBW91	GSBW80	GSBW69	GSBW58
1	1.3849+03	1.3851+03	1.4272+03	1.3967+03	1.4004+03	1.3940+03
2	1.4149+03	1.4152+03	1.4531+03	1.4270+03	1.4315+03	1.4250+03
3	1.5045+03	1.5048+03	1.5410+03	1.5196+03	1.5255+03	1.5212+03
4	1.6166+03	1.6169+03	1.6317+03	1.6313+03	1.6388+03	1.6374+03
5	1.6370+03	1.6377+03	1.6510+03	1.6533+03	1.6622+03	1.6614+03
6	1.6745+03	1.6746+03	1.6890+03	1.6978+03	1.7035+03	1.7016+03
7	1.6822+03	1.6825+03	1.6998+03	1.7051+03	1.7098+03	1.7090+03
8	1.8029+03	1.8033+03	1.8085+03	1.8227+03	1.8249+03	1.8292+03
9	1.7904+03	1.7907+03	1.7968+03	1.8110+03	1.8126+03	1.6776+03
10	1.7928+03	1.7931+03	1.8021+03	1.8146+03	1.8168+03	1.8222+03
11	1.7873+03	1.7873+03	1.7995+03	1.8120+03	1.8145+03	1.8204+03
12	1.7804+03	1.7806+03	1.7948+03	1.8067+03	1.8102+03	1.8153+03
13	1.7789+03	1.7795+03	1.7981+03	1.8057+03	1.8081+03	1.8152+03
14	1.7780+03	1.7786+03	1.7975+03	1.8074+03	1.8097+03	1.8174+03
15	1.7572+03	1.7567+03	1.7787+03	1.7917+03	1.7973+03	1.8014+03
16	1.7802+03	1.7800+03	1.8066+03	1.8149+03	1.8181+03	1.7334+03
17	1.7594+03	1.7594+03	1.7846+03	1.7944+03	1.7989+03	1.6452+03
18	1.7813+03	1.7814+03	1.8074+03	1.8144+03	1.8161+03	1.8252+03
19	1.7763+03	1.7766+03	1.7957+03	1.8095+03	1.8128+03	1.5533+03
20	1.7793+03	1.7789+03	1.7932+03	1.8107+03	1.8139+03	1.8204+03
21	1.7769+03	1.7764+03	1.7908+03	1.8058+03	1.8103+03	1.8169+03
22	1.7712+03	1.7712+03	1.7816+03	1.7993+03	1.8039+03	1.8099+03
23	1.7654+03	1.7665+03	1.7793+03	1.7911+03	1.7939+03	1.8042+03
24	1.7775+03	1.7772+03	1.7908+03	1.8058+03	1.8096+03	1.8162+03
25	1.8087+03	1.8082+03	1.8372+03	1.8408+03	1.8481+03	1.8528+03
26	1.6122+03	1.6125+03	1.6340+03	1.6470+03	1.6311+03	1.6321+03
27	1.6135+03	1.6136+03	1.6379+03	1.6564+03	1.6313+03	1.6332+03
28	1.6210+03	1.6209+03	1.6443+03	1.6658+03	1.6381+03	1.6407+03
29	1.6383+03	1.6379+03	1.6627+03	1.6506+03	1.6562+03	1.6589+03
30	1.6439+03	1.6441+03	1.6690+03	1.6957+03	1.6634+03	1.6667+03
31	1.6706+03	1.6703+03	1.6939+03	1.7199+03	1.6910+03	1.6948+03
32	1.7025+03	1.7031+03	1.7349+03	1.7383+03	1.7308+03	1.7348+03
33	1.7262+03	1.7267+03	1.7467+03	1.7455+03	1.7519+03	1.7575+03
34	1.7132+03	1.7126+03	1.7265+03	1.7300+03	1.7342+03	1.7401+03
35	1.7319+03	1.7324+03	1.7537+03	1.7515+03	1.7578+03	1.7629+03
36	1.7612+03	1.7612+03	1.7970+03	1.7892+03	1.7895+03	1.7919+03
37	1.7919+03	1.7917+03	1.8168+03	1.8176+03	1.8255+03	1.8346+03
38	1.7754+03	1.7752+03	1.7895+03	1.7984+03	1.8052+03	1.8151+03
39	1.7637+03	1.7640+03	1.7775+03	1.7877+03	1.7922+03	1.8022+03
40	1.7436+03	1.7441+03	1.7602+03	1.7662+03	1.7735+03	1.7108+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	362	374	384	392	403	414
	GSBW47	GSBW36	GSBW25	USBW58	USBW47	USBW36
1	1.4067+03	1.4092+03	1.4075+03	1.4075+03	1.4030+03	1.4069+03
2	1.4373+03	1.4403+03	1.4386+03	1.4373+03	1.4338+03	1.4379+03
3	1.5314+03	1.5347+03	1.5334+03	1.5302+03	1.5290+03	1.5332+03
4	1.6445+03	1.6480+03	1.6480+03	1.6408+03	1.6427+03	1.6467+03
5	1.6683+03	1.6718+03	1.6722+03	1.6637+03	1.6665+03	1.6706+03
6	1.7064+03	1.7101+03	1.7104+03	1.7032+03	1.7052+03	1.7089+03
7	1.7134+03	1.7167+03	1.7169+03	1.7098+03	1.7121+03	1.7158+03
8	1.8287+03	1.8319+03	1.8310+03	1.8241+03	1.8285+03	1.8310+03
9	1.8182+03	1.8224+03	1.8210+03	1.8128+03	1.8179+03	1.8213+03
10	1.8226+03	1.8287+03	1.8264+03	1.8174+03	1.8227+03	1.8263+03
11	1.8218+03	1.8291+03	1.8199+03	1.8161+03	1.8214+03	1.8256+03
12	1.8171+03	1.8252+03	1.8210+03	1.8121+03	1.8170+03	1.8217+03
13	1.8163+03	1.8239+03	1.8223+03	1.8104+03	1.8162+03	1.8216+03
14	1.8196+03	1.8279+03	1.8272+03	1.8122+03	1.8192+03	1.8252+03
15	1.8058+03	1.8143+03	1.8126+03	1.7994+03	1.8051+03	1.8106+03
16	1.8294+03	1.8389+03	1.8374+03	1.8214+03	1.8288+03	1.8351+03
17	1.8067+03	1.8155+03	1.8136+03	1.8012+03	1.8062+03	1.8119+03
18	1.8267+03	1.8364+03	1.8358+03	1.8205+03	1.8268+03	1.8328+03
19	1.8211+03	1.8310+03	1.8409+03	1.8182+03	1.8220+03	1.8277+03
20	1.8229+03	1.8337+03	1.8459+03	1.8195+03	1.8234+03	1.8287+03
21	1.8192+03	1.8300+03	1.8430+03	1.8144+03	1.8191+03	1.8253+03
22	1.8132+03	1.8240+03	1.8373+03	1.8083+03	1.8130+03	1.8194+03
23	1.8074+03	1.8195+03	1.8338+03	1.8020+03	1.8077+03	1.8153+03
24	1.8213+03	1.8308+03	1.8402+03	1.8159+03	1.8208+03	1.8248+03
25	1.8555+03	1.8629+03	1.8681+03	1.8505+03	1.8554+03	1.8557+03
26	1.6443+03	1.6551+03	1.6647+03	1.6409+03	1.6436+03	1.6521+03
27	1.6448+03	1.6557+03	1.6646+03	1.6417+03	1.6440+03	1.6516+03
28	1.6523+03	1.6632+03	1.6720+03	1.6492+03	1.6514+03	1.6596+03
29	1.6700+03	1.6814+03	1.6903+03	1.6650+03	1.6689+03	1.6772+03
30	1.6780+03	1.6895+03	1.6988+03	1.6740+03	1.6770+03	1.6853+03
31	1.7062+03	1.7175+03	1.7276+03	1.7016+03	1.7054+03	1.7136+03
32	1.7434+03	1.7535+03	1.7614+03	1.7384+03	1.7427+03	1.7492+03
33	1.7658+03	1.7804+03	1.7901+03	1.7606+03	1.7671+03	1.7757+03
34	1.7484+03	1.7606+03	1.7718+03	1.7446+03	1.7484+03	1.7565+03
35	1.7710+03	1.7856+03	1.7953+03	1.7656+03	1.7713+03	1.7811+03
36	1.7959+03	1.8032+03	1.8080+03	1.7920+03	1.7941+03	1.7955+03
37	1.8419+03	1.8629+03	1.8681+03	1.8340+03	1.8437+03	1.8526+03
38	1.8212+03	1.8426+03	1.8509+03	1.8131+03	1.8230+03	1.8328+03
39	1.8102+03	1.8276+03	1.8378+03	1.8037+03	1.8110+03	1.8203+03
40	1.7883+03	1.8065+03	1.8151+03	1.7809+03	1.7890+03	1.7981+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	424	475	477	479	480	482
	USBW25	SIT-I	SIT	SIT	SOT-I	SOT
1	1.3969+03	1.2135+03	1.2147+03	1.2147+03	1.3528+03	1.3553+03
2	1.4279+03	1.2377+03	1.2389+03	1.2387+03	1.3763+03	1.3781+03
3	1.5223+03	1.2663+03	1.2679+03	1.2678+03	1.4329+03	1.4360+03
4	1.6352+03	1.3272+03	1.3283+03	1.3283+03	1.4887+03	1.4912+03
5	1.6592+03	1.3062+03	1.3072+03	1.3069+03	1.4930+03	1.4957+03
6	1.6963+03	1.3764+03	1.3780+03	1.3778+03	1.5371+03	1.5406+03
7	1.7027+03	1.4099+03	1.4108+03	1.4105+03	1.5506+03	1.5524+03
8	1.8079+03	1.6503+03	1.6513+03	1.6508+03	1.7157+03	1.7170+03
9	1.7973+03	1.6199+03	1.6209+03	1.6204+03	1.6913+03	1.6928+03
10	1.8019+03	1.5860+03	1.5869+03	1.5864+03	1.6709+03	1.6729+03
11	1.8013+03	1.5070+03	1.5075+03	1.5070+03	1.6254+03	1.6270+03
12	1.7974+03	1.4469+03	1.4473+03	1.4468+03	1.5912+03	1.5927+03
13	1.7967+03	1.4269+03	1.4269+03	1.4264+03	1.5854+03	1.5854+03
14	1.8004+03	1.3590+03	1.3575+03	1.3575+03	1.5312+03	1.5331+03
15	1.7876+03	1.2209+03	1.2204+03	1.2199+03	1.4993+03	1.5025+03
16	1.8108+03	1.2379+03	1.2360+03	1.2357+03	1.5044+03	1.5066+03
17	1.7864+03	1.2173+03	1.2155+03	1.2150+03	1.5368+03	1.5359+03
18	1.8060+03	1.2445+03	1.2434+03	1.2430+03	1.5413+03	1.5416+03
19	1.8003+03	1.2234+03	1.2246+03	1.2239+03	1.5276+03	1.5311+03
20	1.8020+03	1.1907+03	1.1917+03	1.1923+03	1.5139+03	1.5171+03
21	1.7990+03	1.1046+03	1.1030+03	1.1030+03	1.4957+03	1.4960+03
22	1.7932+03	1.0694+03	1.0682+03	1.0682+03	1.4792+03	1.4804+03
23	1.7893+03	1.0193+03	1.0192+03	1.0185+03	1.4531+03	1.4541+03
24	1.7973+03	8.9837+02	8.9791+02	8.9791+02	1.3978+03	1.3989+03
25	1.8339+03	8.5580+02	8.5744+02	8.5744+02	1.5223+03	1.5236+03
26	1.6265+03	1.0583+03	1.0587+03	1.0583+03	1.4022+03	1.4047+03
27	1.6258+03	1.0562+03	1.0564+03	1.0560+03	1.4224+03	1.4254+03
28	1.6334+03	1.1233+03	1.1230+03	1.1221+03	1.4456+03	1.4480+03
29	1.6504+03	1.1495+03	1.1505+03	1.1495+03	1.4634+03	1.4661+03
30	1.6576+03	1.1699+03	1.1712+03	1.1702+03	1.4753+03	1.4787+03
31	1.6854+03	1.2018+03	1.2025+03	1.2025+03	1.5118+03	1.5155+03
32	1.7161+03	1.2221+03	1.2222+03	1.2215+03	1.5129+03	1.5138+03
33	1.7454+03	1.2922+03	1.2923+03	1.2916+03	1.5611+03	1.5653+03
34	1.7274+03	1.3280+03	1.3294+03	1.3285+03	1.5561+03	1.5600+03
35	1.7501+03	1.3037+03	1.3026+03	1.3018+03	1.5834+03	1.5855+03
36	1.7597+03	1.2787+03	1.2795+03	1.2792+03	1.5899+03	1.5928+03
37	1.8177+03	1.3533+03	1.3555+03	1.3548+03	1.6005+03	1.6047+03
38	1.7988+03	1.3592+03	1.3587+03	1.3577+03	1.5914+03	1.5932+03
39	1.7867+03	1.3460+03	1.3455+03	1.3448+03	1.5695+03	1.5730+03
40	1.7647+03	1.3224+03	1.3210+03	1.3205+03	1.5443+03	1.5449+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	484	486	488	490	492	494
SOT		BI93	BI80	BI69	BI58	BI47
1	1.3550+03	1.2236+03	1.2530+03	1.2779+03	1.3013+03	1.3276+03
2	1.3781+03	1.2478+03	1.2771+03	1.3031+03	1.3285+03	1.3551+03
3	1.4353+03	1.2768+03	1.3143+03	1.3488+03	1.3826+03	1.4207+03
4	1.4907+03	1.3393+03	1.3757+03	1.4118+03	1.4521+03	1.5001+03
5	1.4952+03	1.3184+03	1.3618+03	1.4044+03	1.4523+03	1.5112+03
6	1.5399+03	1.3911+03	1.4891+03	1.5529+03	1.6082+03	1.6463+03
7	1.5519+03	1.4210+03	1.5227+03	1.5790+03	1.6275+03	1.6538+03
8	1.7167+03	1.6609+03	1.7257+03	1.7606+03	1.7809+03	1.7698+03
9	1.6920+03	1.6303+03	1.7035+03	1.7426+03	1.7637+03	1.7541+03
10	1.6724+03	1.5988+03	1.6902+03	1.7352+03	1.7582+03	1.7481+03
11	1.6266+03	1.5225+03	1.6518+03	1.7101+03	1.7423+03	1.7308+03
12	1.5921+03	1.4641+03	1.6235+03	1.6919+03	1.7309+03	1.7190+03
13	1.5856+03	1.4440+03	1.6130+03	1.6849+03	1.7282+03	1.7167+03
14	1.5327+03	1.3789+03	1.5864+03	1.6716+03	1.7221+03	1.7093+03
15	1.5025+03	1.2464+03	1.5025+03	1.6065+03	1.6954+03	1.6941+03
16	1.5061+03	1.2631+03	1.5283+03	1.6381+03	1.7208+03	1.7083+03
17	1.5359+03	1.2415+03	1.4918+03	1.6004+03	1.6865+03	1.7001+03
18	1.5418+03	1.2718+03	1.5356+03	1.6462+03	1.7215+03	1.7095+03
19	1.5300+03	1.2555+03	1.5423+03	1.6568+03	1.7142+03	1.7018+03
20	1.5166+03	1.2339+03	1.5608+03	1.6807+03	1.7091+03	1.6970+03
21	1.4959+03	1.1668+03	1.5694+03	1.6973+03	1.7012+03	1.6898+03
22	1.4799+03	1.1592+03	1.6056+03	1.6998+03	1.6937+03	1.6818+03
23	1.4536+03	1.1948+03	1.6946+03	1.6911+03	1.6850+03	1.6704+03
24	1.3991+03					
25	1.5236+03					
26	1.4040+03					
27	1.4247+03					
28	1.4477+03					
29	1.4661+03					
30	1.4786+03					
31	1.5149+03					
32	1.5140+03					
33	1.5643+03					
34	1.5592+03					
35	1.5847+03					
36	1.5927+03					
37	1.6042+03					
38	1.5927+03					
39	1.5717+03					
40	1.5446+03					

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	496	498	502	505	506	507
	BI36	BI25	BIP	BOP	DP-B	TSAT-I
1	1.3456+03	1.3677+03	3.2355+01	8.3879+00	2.3967+01	1.5674+03
2	1.3724+03	1.3960+03	3.3543+01	7.0747+00	2.6468+01	1.5754+03
3	1.4454+03	1.4784+03	3.8635+01	1.1632+01	2.7003+01	1.6095+03
4	1.5393+03	1.5305+03	4.9243+01	2.4532+01	2.4711+01	1.6696+03
5	1.5583+03	1.5416+03	5.1195+01	2.5073+01	2.6122+01	1.6788+03
6	1.6305+03	1.5868+03	5.9201+01	3.1098+01	2.8103+01	1.7124+03
7	1.6377+03	1.5964+03	6.1238+01	3.2720+01	2.8517+01	1.7209+03
8	1.7583+03	1.7363+03	8.7348+01	6.0992+01	2.6356+01	1.8234+03
9	1.7407+03	1.7145+03	8.3812+01	5.6821+01	2.6991+01	1.8120+03
10	1.7334+03	1.7008+03	8.2596+01	5.2109+01	3.0487+01	1.8080+03
11	1.7138+03	1.6689+03	7.8352+01	4.2917+01	3.5436+01	1.7927+03
12	1.7002+03	1.6474+03	7.5128+01	3.9673+01	3.5455+01	1.7792+03
13	1.6985+03	1.6428+03	7.4279+01	3.4265+01	4.0014+01	1.7756+03
14	1.6887+03	1.6213+03	7.1987+01	2.9167+01	4.2820+01	1.7660+03
15	1.6748+03	1.6079+03	7.0036+01	2.6463+01	4.3572+01	1.7578+03
16	1.6879+03	1.6160+03	7.0856+01	2.3683+01	4.7173+01	1.7613+03
17	1.6825+03	1.6226+03	7.1167+01	3.3802+01	3.7365+01	1.7626+03
18	1.6899+03	1.6260+03	7.3119+01	3.2798+01	4.0321+01	1.7707+03
19	1.6825+03	1.6155+03	6.9187+01	3.3725+01	3.5462+01	1.7543+03
20	1.6767+03	1.6049+03	6.7744+01	3.1793+01	3.5951+01	1.7482+03
21	1.6682+03	1.5888+03	6.6895+01	2.3451+01	4.3445+01	1.7446+03
22	1.6580+03	1.5724+03	6.6363+01	2.5464+01	4.0899+01	1.7424+03
23	1.6411+03	1.5461+03	6.4944+01	1.7503+01	4.7441+01	1.7365+03
24			6.0446+01	1.6576+01	4.3870+01	1.7176+03
25			6.3784+01	1.7194+01	4.6590+01	1.7316+03
26			4.2114+01	1.6112+01	2.6002+01	1.6303+03
27			4.2737+01	1.4181+01	2.8555+01	1.6338+03
28			4.3783+01	1.6267+01	2.7516+01	1.6395+03
29			4.3840+01	1.4259+01	2.9581+01	1.6399+03
30			4.7093+01	2.0361+01	2.6732+01	1.6578+03
31			5.0488+01	1.5108+01	3.5380+01	1.6758+03
32			4.7942+01	1.6730+01	3.1211+01	1.6625+03
33			5.8437+01	2.7159+01	3.1278+01	1.7092+03
34			5.6146+01	2.7004+01	2.9141+01	1.6996+03
35			5.8437+01	2.2447+01	3.5990+01	1.7092+03
36			5.0516+01	1.8353+01	3.2164+01	1.6760+03
37			6.8593+01	3.8977+01	2.9616+01	1.7518+03
38			6.6924+01	3.5192+01	3.1732+01	1.7448+03
39			6.6008+01	3.6757+01	2.9251+01	1.7409+03
40			6.1238+01	3.5347+01	2.5891+01	1.7209+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	508	512	521	526	530	537
	DTSC	QSC	QL	QPRI	QFLUX	QUAL-B
1	3.5391+02	1.3256+02	5.0318+00	3.6468+01	9.6462+04	-8.9541-03
2	3.3766+02	1.2413+02	5.5043+00	3.2323+01	8.5499+04	-1.1137-02
3	3.4322+02	1.2430+02	7.0077+00	4.3755+01	1.1574+05	-1.0105-02
4	3.4244+02	1.0842+02	9.1889+00	7.6831+01	2.0323+05	2.0966-02
5	3.7260+02	1.1347+02	9.6568+00	9.0834+01	2.4027+05	2.8645-02
6	3.3595+02	9.3441+01	1.0443+01	9.4516+01	2.5001+05	4.6445-02
7	3.1107+02	8.6415+01	1.0610+01	9.0769+01	2.4009+05	4.8516-02
8	1.7310+02	4.9628+01	1.3590+01	6.8575+01	1.8139+05	4.9312-02
9	1.9206+02	5.4373+01	1.3220+01	7.4933+01	1.9821+05	5.4116-02
10	2.2201+02	5.8766+01	1.3280+01	8.9641+01	2.3711+05	7.0220-02
11	2.8567+02	6.8605+01	1.3188+01	1.1091+02	2.9338+05	9.2591-02
12	3.3224+02	7.4709+01	1.3067+01	1.2403+02	3.2808+05	1.0786-01
13	3.4872+02	7.7855+01	1.3084+01	1.2650+02	3.3461+05	1.0768-01
14	4.0697+02	8.4752+01	1.3176+01	1.4300+02	3.7825+05	1.3248-01
15	5.3688+02	1.1517+02	1.2661+01	1.6584+02	4.3866+05	1.2513-01
16	5.2337+02	1.0172+02	1.3100+01	1.3377+02	3.5384+05	1.0732-01
17	5.4526+02	1.2115+02	1.2587+01	1.6748+02	4.4300+05	1.1122-01
18	5.2629+02	1.0195+02	1.3268+01	1.6332+02	4.3199+05	1.3990-01
19	5.3090+02	9.0536+01	1.3305+01	1.5614+02	4.1301+05	1.5505-01
20	5.5753+02	7.9105+01	1.3505+01	1.6101+02	4.2588+05	2.0366-01
21	6.4003+02	7.1723+01	1.3500+01	1.6509+02	4.3668+05	2.6752-01
22	6.7304+02	5.8940+01	1.3378+01	1.6403+02	4.3387+05	3.5813-01
23	7.1713+02	4.1974+01	1.3244+01	1.6020+02	4.2376+05	5.5566-01
24	8.1923+02	2.5012+01	1.3401+01	1.4782+02	3.9101+05	1.0200+00
25	8.7580+02	2.5286+01	1.4100+01	1.3076+02	3.4588+05	9.3225-01
26	5.7201+02	1.5064+01	9.3368+00	7.5988+01	2.0100+05	5.9810-01
27	5.7758+02	1.6567+01	9.3975+00	7.3114+01	1.9340+05	5.1630-01
28	5.1626+02	1.5033+01	9.6013+00	7.2777+01	1.9250+05	5.2095-01
29	4.9038+02	1.4750+01	1.0001+01	7.4999+01	1.9838+05	5.2489-01
30	4.8789+02	1.4192+01	1.0158+01	7.7484+01	2.0495+05	5.7192-01
31	4.7401+02	1.3932+01	1.0815+01	8.0995+01	2.1424+05	6.0148-01
32	4.4032+02	9.4108+00	1.1635+01	8.1734+01	2.1620+05	8.6870-01
33	4.1695+02	1.4513+01	1.2278+01	9.1989+01	2.4332+05	6.0079-01
34	3.7153+02	1.4272+01	1.1816+01	8.3037+01	2.1964+05	4.9010-01
35	4.0552+02	1.3491+01	1.2403+01	8.9069+01	2.3560+05	6.1112-01
36	3.9726+02	6.5078+00	1.2874+01	4.9622+01	1.3126+05	6.8743-01
37	3.9849+02	1.6904+01	1.4171+01	1.1697+02	3.0940+05	6.5107-01
38	3.8557+02	1.4725+01	1.3628+01	1.1009+02	2.9121+05	6.8554-01
39	3.9491+02	1.6682+01	1.3189+01	1.0660+02	2.8196+05	5.9021-01
40	3.9853+02	1.7338+01	1.2603+01	1.0506+02	2.7789+05	5.5576-01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	538	542	543	544	548	549
	MFV-B	VVEL-B	DTO-SO	DTO-SI	DTLM-0	U0
1	-1.6990-02	-1.6048+02	4.8061+01	1.7010+02	9.6555+01	9.9903+02
2	-2.0658-02	-1.7275+02	5.5966+01	1.7675+02	1.0503+02	8.1405+02
3	-1.8319-02	-1.1852+02	9.5682+01	2.3966+02	1.5681+02	7.3808+02
4	3.2744-02	1.6657+02	1.5725+02	2.9399+02	2.1853+02	9.2997+02
5	4.3081-02	2.1540+02	1.7802+02	3.3590+02	2.4866+02	9.6623+02
6	6.2850-02	2.6330+02	1.7321+02	3.0318+02	2.3216+02	1.0769+03
7	6.5160-02	2.5970+02	1.6774+02	2.7886+02	2.1861+02	1.0983+03
8	6.5146-02	1.4207+02	1.2193+02	1.6283+02	1.4140+02	1.2828+03
9	7.1060-02	1.6865+02	1.3573+02	1.8093+02	1.5724+02	1.2605+03
10	8.6776-02	2.2113+02	1.6221+02	2.1663+02	1.8811+02	1.2605+03
11	1.0522-01	3.1499+02	2.0850+02	2.9020+02	2.4711+02	1.1873+03
12	1.1577-01	3.9258+02	2.3970+02	3.4367+02	2.8857+02	1.1369+03
13	1.1510-01	3.9892+02	2.4541+02	3.6262+02	3.0021+02	1.1146+03
14	1.3351-01	5.7193+02	3.0408+02	4.2998+02	3.6340+02	1.0409+03
15	1.3233-01	6.4542+02	3.2006+02	5.4537+02	4.2276+02	1.0376+03
16	1.0256-01	4.8955+02	3.3074+02	5.5345+02	4.3258+02	8.1797+02
17	1.2180-01	5.1088+02	2.8650+02	5.5318+02	4.0532+02	1.0930+03
18	1.3298-01	5.4843+02	3.0264+02	5.4742+02	4.1301+02	1.0460+03
19	1.3037-01	5.6634+02	3.0895+02	5.6313+02	4.2340+02	9.7545+02
20	1.4310-01	6.5642+02	3.2558+02	5.9704+02	4.4767+02	9.5132+02
21	1.4991-01	7.4170+02	3.4226+02	6.8139+02	4.9252+02	8.8664+02
22	1.5744-01	8.3350+02	3.5287+02	7.1088+02	5.1115+02	8.4881+02
23	1.6420-01	9.7724+02	3.7394+02	7.5704+02	5.4316+02	7.8018+02
24	1.5917-01	1.2043+03	4.3561+02	8.8767+02	6.3505+02	6.1571+02
25	1.3777-01	6.1096+02	3.3810+02	9.6232+02	5.9677+02	5.7959+02
26	8.0393-02	5.9624+02	2.5397+02	5.5813+02	3.8629+02	5.2032+02
27	7.5568-02	5.1125+02	2.3328+02	5.6107+02	3.7350+02	5.1779+02
28	7.6849-02	4.7229+02	2.1811+02	5.0177+02	3.4047+02	5.6541+02
29	7.9761-02	4.5251+02	2.1806+02	4.9193+02	3.3663+02	5.8932+02
30	8.3681-02	4.5030+02	2.1390+02	4.7801+02	3.2844+02	6.2401+02
31	8.8437-02	4.0926+02	2.0692+02	4.7343+02	3.2200+02	6.6535+02
32	9.2838-02	4.2759+02	2.4111+02	4.8739+02	3.4992+02	6.1784+02
33	1.0289-01	3.9229+02	2.2170+02	4.4081+02	3.1881+02	7.6323+02
34	9.2367-02	3.5973+02	2.0742+02	3.9006+02	2.8919+02	7.5950+02
35	9.9896-02	3.4878+02	2.0592+02	4.3722+02	3.0719+02	7.6694+02
36	5.5816-02	1.9018+02	2.0830+02	4.8948+02	3.2911+02	3.9882+02
37	1.3400-01	4.3934+02	2.6270+02	4.4633+02	3.4644+02	8.9307+02
38	1.2704-01	4.3053+02	2.5259+02	4.2488+02	3.3130+02	8.7899+02
39	1.2126-01	4.4696+02	2.6006+02	4.2737+02	3.3682+02	8.3713+02
40	1.1830-01	4.8266+02	2.6394+02	4.3088+02	3.4062+02	8.1583+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	600	603	605	606	608	610
	VCIT-I	VCIT	VCIT	VCOT-I	VCOT	VCOT
1	1.3509+03	1.3510+03	1.3505+03	1.3408+03	1.3408+03	1.3407+03
2	1.3736+03	1.3747+03	1.3740+03	1.3567+03	1.3562+03	1.3559+03
3	1.4296+03	1.4301+03	1.4295+03	1.3815+03	1.3807+03	1.3811+03
4	1.4850+03	1.4860+03	1.4853+03	1.4312+03	1.4303+03	1.4301+03
5	1.4884+03	1.4897+03	1.4887+03	1.4205+03	1.4195+03	1.4196+03
6	1.5339+03	1.5342+03	1.5334+03	1.4825+03	1.4817+03	1.4818+03
7	1.5459+03	1.5464+03	1.5459+03	1.5005+03	1.5003+03	1.5003+03
8	1.7135+03	1.7140+03	1.7134+03	1.7042+03	1.7043+03	1.7043+03
9	1.6886+03	1.6896+03	1.6885+03	1.6760+03	1.6756+03	1.6757+03
10	1.6688+03	1.6699+03	1.6688+03	1.6508+03	1.6498+03	1.6502+03
11	1.6212+03	1.6224+03	1.6215+03	1.5886+03	1.5874+03	1.5874+03
12	1.5850+03	1.5854+03	1.5845+03	1.5342+03	1.5334+03	1.5336+03
13	1.5768+03	1.5799+03	1.5788+03	1.5192+03	1.5178+03	1.5176+03
14	1.5174+03	1.5192+03	1.5182+03	1.4544+03	1.4530+03	1.4528+03
15	1.4815+03	1.4814+03	1.4811+03	1.3769+03	1.3748+03	1.3755+03
16	1.4838+03	1.4866+03	1.4856+03	1.3776+03	1.3750+03	1.3754+03
17	1.5253+03	1.5242+03	1.5232+03	1.3815+03	1.3794+03	1.3819+03
18	1.5294+03	1.5304+03	1.5288+03	1.4010+03	1.3980+03	1.4000+03
19	1.5187+03	1.5174+03	1.5167+03	1.3909+03	1.3899+03	1.3925+03
20	1.5046+03	1.5036+03	1.5026+03	1.3778+03	1.3763+03	1.3783+03
21	1.4831+03	1.4844+03	1.4849+03	1.3404+03	1.3390+03	1.3400+03
22	1.4667+03	1.4655+03	1.4657+03	1.3291+03	1.3285+03	1.3299+03
23	1.4407+03	1.4435+03	1.4427+03	1.3137+03	1.3111+03	1.3116+03
24	1.3854+03	1.3882+03	1.3879+03	1.2861+03	1.2849+03	1.2849+03
25	1.4199+03	1.4206+03	1.4186+03	1.2903+03	1.2905+03	1.2900+03
26	1.3985+03	1.3996+03	1.3989+03	1.3754+03	1.3753+03	1.3753+03
27	1.4202+03	1.4218+03	1.4207+03	1.4028+03	1.4020+03	1.4021+03
28	1.4436+03	1.4446+03	1.4439+03	1.4296+03	1.4294+03	1.4292+03
29	1.4616+03	1.4647+03	1.4630+03	1.4494+03	1.4475+03	1.4480+03
30	1.4740+03	1.4754+03	1.4752+03	1.4626+03	1.4639+03	1.4639+03
31	1.5105+03	1.5140+03	1.5124+03	1.5021+03	1.5004+03	1.5004+03
32	1.5092+03	1.5119+03	1.5102+03	1.5011+03	1.4996+03	1.4992+03
33	1.5613+03	1.5606+03	1.5601+03	1.5525+03	1.5521+03	1.5524+03
34	1.5549+03	1.5566+03	1.5566+03	1.5462+03	1.5465+03	1.5466+03
35	1.5826+03	1.5825+03	1.5811+03	1.5759+03	1.5733+03	1.5734+03
36	1.5590+03	1.5617+03	1.5604+03	1.5329+03	1.5303+03	1.5308+03
37	1.6000+03	1.6000+03	1.6000+03	1.5898+03	1.5909+03	1.5916+03
38	1.5889+03	1.5917+03	1.5894+03	1.5798+03	1.5772+03	1.5774+03
39	1.5672+03	1.5699+03	1.5696+03	1.5551+03	1.5552+03	1.5550+03
40	1.5417+03	1.5416+03	1.5408+03	1.5263+03	1.5265+03	1.5265+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	611	613	614	616	618	622
	SP VCO	DP-VC	HCOT-I	HCOT	HCOT	HCAI
1	5.5882+02	3.0592+00	1.2104+03	1.2109+03	1.2095+03	5.9114+01
2	5.6362+02	5.0987+00	1.2382+03	1.2357+03	1.2349+03	5.9158+01
3	5.7111+02	1.4498+01	1.2594+03	1.2602+03	1.2583+03	5.6188+01
4	5.8611+02	1.6295+01	1.3335+03	1.3359+03	1.3341+03	5.5528+01
5	5.8289+02	2.0571+01	1.3159+03	1.3160+03	1.3141+03	5.2010+01
6	6.0165+02	1.5599+01	1.4027+03	1.4052+03	1.4034+03	5.3827+01
7	6.0712+02	1.3814+01	1.4250+03	1.4261+03	1.4237+03	5.9796+01
8	6.6962+02	2.8616+00	1.6767+03	1.6778+03	1.6759+03	8.4656+01
9	6.6089+02	3.8932+00	1.6428+03	1.6447+03	1.6426+03	7.7264+01
10	6.5309+02	5.5695+00	1.6102+03	1.6122+03	1.6102+03	6.8794+01
11	6.3401+02	9.9763+00	1.5320+03	1.5328+03	1.5312+03	5.6672+01
12	6.1735+02	1.5557+01	1.4591+03	1.4586+03	1.4567+03	4.8054+01
13	6.1280+02	1.7577+01	1.4377+03	1.4380+03	1.4365+03	4.3638+01
14	5.9314+02	1.9109+01	1.3359+03	1.3344+03	1.3331+03	4.5478+01
15	5.6973+02	3.1617+01	1.2102+03	1.2086+03	1.2079+03	4.0786+01
16	5.6994+02	3.2119+01	1.2173+03	1.2068+03	1.2056+03	3.9337+01
17	5.7111+02	4.3540+01	1.2253+03	1.2345+03	1.2247+03	3.2000+01
18	5.7699+02	3.8909+01	1.2541+03	1.2484+03	1.2462+03	3.2000+01
19	5.7395+02	3.8693+01	1.2270+03	1.2313+03	1.2284+03	3.2000+01
20	5.6999+02	3.8372+01	1.2025+03	1.2054+03	1.2028+03	3.2000+01
21	5.5872+02	4.3135+01	1.1055+03	1.1049+03	1.1026+03	3.2000+01
22	5.5530+02	4.1563+01	1.0756+03	1.0734+03	1.0717+03	3.2000+01
23	5.5068+02	3.8306+01	1.0242+03	1.0222+03	1.0211+03	3.5404+01
24	5.4238+02	2.9901+01	8.7532+02	8.7164+02	8.7090+02	4.1867+01
25	5.4367+02	3.9022+01	6.7842+02	6.7519+02	6.7615+02	4.5501+01
26	5.6928+02	6.9587+00	1.1633+03	1.1647+03	1.1634+03	4.1246+01
27	5.7755+02	5.2399+00	1.2803+03	1.2811+03	1.2797+03	4.3477+01
28	5.8561+02	4.2391+00	1.2922+03	1.2929+03	1.2917+03	4.4305+01
29	5.9162+02	3.6812+00	1.3301+03	1.3299+03	1.3287+03	4.5984+01
30	5.9561+02	3.4774+00	1.3455+03	1.3500+03	1.3476+03	4.5754+01
31	6.0761+02	2.5393+00	1.4230+03	1.4238+03	1.4228+03	4.6283+01
32	6.0732+02	2.4397+00	1.3908+03	1.3885+03	1.3871+03	4.4443+01
33	6.2293+02	2.7117+00	1.4876+03	1.4904+03	1.4869+03	4.4466+01
34	6.2103+02	2.6554+00	1.4577+03	1.4568+03	1.4545+03	4.7870+01
35	6.3013+02	2.0347+00	1.5266+03	1.5303+03	1.5282+03	4.7042+01
36	6.1696+02	7.9862+00	1.4411+03	1.4188+03	1.4176+03	5.0400+01
37	6.3436+02	3.1413+00	1.5400+03	1.5440+03	1.5394+03	4.5110+01
38	6.3132+02	2.7907+00	1.5044+03	1.5012+03	1.4986+03	4.6697+01
39	6.2374+02	3.7111+00	1.4629+03	1.4633+03	1.4600+03	5.2125+01
40	6.1495+02	4.6816+00	1.4286+03	1.4311+03	1.4268+03	5.0124+01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	624	626	628	630	632	634
	HCAI	HCAO-H	HCO-T	3HA9	9HA9	3HA21
1	5.6474+01	9.4582+02	1.4799+02	2.2311+02	1.9363+02	4.3423+02
2	5.5638+01	9.9710+02	1.4760+02	1.7653+02	1.7191+02	4.2523+02
3	5.2562+01	1.0018+03	1.5079+02	1.3583+02	1.4111+02	3.9423+02
4	5.1872+01	1.0703+03	1.5365+02	1.4089+02	1.4837+02	4.1177+02
5	4.8330+01	1.0112+03	1.5774+02	1.2694+02	1.3090+02	3.6906+02
6	4.9687+01	1.1080+03	1.5992+02	1.3836+02	1.4628+02	4.1051+02
7	5.5836+01	1.1402+03	1.5704+02	1.4692+02	1.5616+02	4.2589+02
8	7.8936+01	1.4850+03	1.4802+02	3.0278+02	3.3382+02	7.2551+02
9	7.1984+01	1.4336+03	1.5734+02	2.4705+02	2.7282+02	6.3581+02
10	6.4394+01	1.3751+03	1.6725+02	2.0155+02	2.2267+02	5.5347+02
11	5.3068+01	1.2184+03	1.7626+02	1.4511+02	1.6183+02	4.2355+02
12	4.5294+01	1.0664+03	1.8008+02	1.1656+02	1.2624+02	3.4693+02
13	4.1338+01	1.0318+03	1.8109+02	1.0881+02	1.1717+02	3.2550+02
14	4.1798+01	1.0414+03	1.7731+02	1.1981+02	1.2861+02	3.5770+02
15	3.8026+01	8.6713+02	1.7932+02	9.6844+01	1.0300+02	2.8685+02
16	3.6117+01	8.5539+02	1.7926+02	9.3698+01	9.5458+01	2.6946+02
17	3.2000+01	1.2385+03	1.8419+02	7.3788+01	7.1588+01	2.1931+02
18	3.2000+01	7.6478+02	1.8144+02	7.4426+01	7.0466+01	2.2303+02
19	3.2000+01	7.5501+02	1.7770+02	7.2270+01	6.6990+01	2.1779+02
20	3.2000+01	7.4377+02	1.7369+02	7.2028+01	6.5868+01	2.1139+02
21	3.2000+01	6.8639+02	1.7000+02	6.9476+01	5.9796+01	1.9916+02
22	3.2000+01	6.9520+02	1.5983+02	7.4910+01	6.6110+01	2.0415+02
23	3.5404+01	6.8373+02	1.5286+02	8.0256+01	6.7496+01	2.0598+02
24	4.0947+01	6.3746+02	1.5332+02	8.2038+01	7.3678+01	2.0468+02
25	4.3661+01	5.3582+02	1.5811+02	8.5514+01	7.3194+01	2.0243+02
26	3.7106+01	9.7445+02	1.5052+02	1.1224+02	1.2060+02	3.4473+02
27	3.9337+01	1.0833+03	1.4562+02	1.3066+02	1.4254+02	3.9214+02
28	4.0165+01	1.1053+03	1.4289+02	1.3453+02	1.4817+02	4.0437+02
29	4.0924+01	1.1347+03	1.4098+02	1.3746+02	1.5154+02	4.1232+02
30	4.1614+01	1.1536+03	1.3988+02	1.4032+02	1.5616+02	4.1899+02
31	4.1683+01	1.2107+03	1.4170+02	1.4654+02	1.6062+02	4.3674+02
32	4.0303+01	1.1897+03	1.4346+02	1.3906+02	1.5534+02	4.2044+02
33	3.9866+01	1.2361+03	1.4524+02	1.4040+02	1.5624+02	4.2691+02
34	4.2810+01	1.2423+03	1.4586+02	1.4806+02	1.6647+02	4.4706+02
35	4.1982+01	1.2810+03	1.4771+02	1.5299+02	1.7033+02	4.5859+02
36	4.5340+01	1.2499+03	1.4608+02	1.7046+02	1.8908+02	4.9348+02
37	4.1430+01	1.2087+03	1.5334+02	1.3002+02	1.4410+02	3.9678+02
38	4.2557+01	1.2007+03	1.5354+02	1.3110+02	1.4430+02	3.9434+02
39	4.8445+01	1.1707+03	1.5301+02	1.3145+02	1.4509+02	3.8721+02
40	4.6444+01	1.1392+03	1.5550+02	1.2734+02	1.4010+02	3.7826+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	636	638	640	642	644	646
	9HA21	3HA33	9HA33	3HA45	3HA57	3HA69
1	3.0187+02	4.5403+02	3.6987+02	9.4295+02	4.3423+02	9.3874+01
2	3.1424+02	5.1348+02	4.1649+02	8.3384+02	5.5044+02	9.1718+01
3	2.7562+02	4.8015+02	4.0303+02	4.8939+02	6.9583+02	9.5788+01
4	2.9149+02	5.0941+02	4.2603+02	5.0325+02	7.2962+02	9.5128+01
5	2.5606+02	4.5190+02	3.7610+02	4.3298+02	6.5758+02	9.9220+01
6	2.8977+02	5.0996+02	4.2431+02	4.9764+02	7.3729+02	9.7438+01
7	3.0652+02	5.2952+02	4.4680+02	5.2116+02	7.6476+02	1.0072+02
8	6.0706+02	9.2365+02	7.9287+02	1.0366+03	1.1946+03	1.0930+02
9	5.1970+02	8.2290+02	7.0854+02	8.9685+02	1.1044+03	1.0718+02
10	4.3731+02	7.1709+02	6.1759+02	7.5027+02	1.0068+03	1.0487+02
11	3.1659+02	5.4927+02	4.6611+02	5.2859+02	7.9514+02	1.0199+02
12	2.4802+02	4.4064+02	3.6792+02	4.0092+02	6.4476+02	1.0116+02
13	2.3223+02	4.1412+02	3.4344+02	3.7381+02	6.1009+02	9.7812+01
14	2.5553+02	4.5885+02	3.8085+02	4.2746+02	6.6937+02	1.0221+02
15	1.9880+02	3.6448+02	2.9648+02	3.2679+02	5.3928+02	1.0124+02
16	1.8862+02	3.4512+02	2.7850+02	3.0522+02	5.1018+02	1.0250+02
17	1.4595+02	2.7884+02	2.1843+02	2.2987+02	4.2074+02	9.9308+01
18	1.4351+02	2.8181+02	2.1775+02	2.3300+02	4.2923+02	9.7746+01
19	1.3871+02	2.7449+02	2.1339+02	2.3052+02	4.2329+02	9.5150+01
20	1.3715+02	2.7155+02	2.1095+02	2.2503+02	4.1476+02	9.2268+01
21	1.2316+02	2.4760+02	1.8728+02	2.0268+02	3.8376+02	8.7956+01
22	1.3035+02	2.5859+02	1.9491+02	2.1075+02	3.9183+02	8.8990+01
23	1.2558+02	2.5646+02	1.9410+02	2.1170+02	3.9234+02	9.0376+01
24	1.3308+02	2.5252+02	1.9544+02	2.1040+02	3.8488+02	9.6558+01
25	1.2995+02	2.4527+02	1.9143+02	2.0991+02	3.7471+02	1.0091+02
26	2.3970+02	4.4072+02	3.6221+02	4.1817+02	6.4442+02	8.5844+01
27	2.8356+02	5.1018+02	4.2040+02	5.0622+02	7.3918+02	8.3578+01
28	2.9496+02	5.2549+02	4.3661+02	5.2637+02	7.6117+02	8.3930+01
29	3.0146+02	5.3678+02	4.4834+02	5.4030+02	7.7943+02	8.5536+01
30	3.0828+02	5.4624+02	4.5692+02	5.5240+02	7.9182+02	8.4876+01
31	3.2722+02	5.7622+02	4.8294+02	5.8796+02	8.2838+02	8.6702+01
32	3.1450+02	5.5334+02	4.6490+02	5.5994+02	8.0238+02	8.5822+01
33	3.2081+02	5.6656+02	4.7812+02	5.7404+02	8.2356+02	9.0244+01
34	3.3985+02	5.9025+02	4.9942+02	6.0453+02	8.5380+02	9.0420+01
35	3.5006+02	6.0763+02	5.1403+02	6.2655+02	8.7287+02	8.8748+01
36	3.8512+02	6.5208+02	5.5596+02	7.0080+02	9.1802+02	8.7120+01
37	2.9163+02	5.2098+02	4.3650+02	5.0646+02	7.6194+02	9.0860+01
38	2.9046+02	5.1414+02	4.3626+02	5.0666+02	7.6126+02	9.5898+01
39	2.8254+02	5.0129+02	4.2398+02	4.8501+02	7.3657+02	9.6690+01
40	2.7502+02	4.8926+02	4.1278+02	4.7122+02	7.1963+02	9.3896+01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	648	650	652	654	656	658
	9HA69	3HA93	9HA93	9HA105	3HA117	9HA117
1	5.4291+02	7.0623+02	7.3515+02	8.2191+02	9.3413+02	3.6811+02
2	6.2819+02	7.7776+02	8.0171+02	8.8332+02	9.9633+02	3.6552+02
3	7.0991+02	8.5388+02	8.4428+02	9.1411+02	1.0187+03	3.9819+02
4	8.1714+02	9.9454+02	9.2776+02	9.9328+02	1.0881+03	4.2925+02
5	7.4655+02	4.1927+02	8.6020+02	9.2327+02	1.0224+03	3.9546+02
6	8.2900+02	1.0379+03	9.7113+02	1.0287+03	1.1372+03	4.3472+02
7	8.6036+02	2.5054+02	1.0016+03	1.0594+03	1.1626+03	4.9564+02
8	1.3115+03	5.2798+02	1.4438+03	1.4799+03	1.5608+03	6.3405+02
9	1.2227+03	7.8203+02	1.3762+03	1.4090+03	1.4940+03	5.6854+02
10	1.1182+03	9.4799+02	1.2840+03	1.3366+03	1.4270+03	6.0615+02
11	9.0072+02	5.4487+02	1.0759+03	1.1512+03	1.2469+03	5.2375+02
12	7.3790+02	7.8888+02	9.1000+02	9.9484+02	1.0828+03	4.8816+02
13	6.9873+02	1.0658+03	8.6609+02	9.4755+02	1.0441+03	4.5533+02
14	7.6801+02	3.2000+01	8.8833+02	9.4167+02	1.0539+03	3.7557+02
15	6.2716+02	3.2000+01	6.9908+02	7.5352+02	8.6084+02	3.2679+02
16	6.0220+02	3.0214+02	6.8232+02	7.3330+02	8.3186+02	3.4144+02
17	4.7135+02	1.0624+03	5.9369+02	6.5811+02	7.7913+02	7.0947+02
18	4.8783+02	1.1623+02	6.0270+02	6.6095+02	7.8604+02	7.2330+02
19	4.8347+02	2.5068+02	6.0400+02	6.3944+02	7.7415+02	6.9211+02
20	4.7971+02	3.7443+02	6.1687+02	6.7255+02	7.5083+02	7.2941+02
21	4.3316+02	4.6968+02	5.4052+02	5.9882+02	7.0164+02	6.5600+02
22	4.3065+02	1.4353+03	5.3935+02	6.1007+02	7.1914+02	6.6495+02
23	4.2336+02	3.9190+02	5.3018+02	5.9735+02	6.9922+02	6.5402+02
24	4.1557+02	3.2000+01	5.2184+02	5.9737+02	6.4835+02	6.3533+02
25	4.0771+02	1.0425+03	5.3191+02	5.3103+02	5.9271+02	5.3103+02
26	7.2622+02	3.9528+02	8.7964+02	9.5166+02	1.0155+03	9.7812+02
27	8.2394+02	1.5474+03	9.7596+02	1.0482+03	1.1261+03	1.0953+03
28	8.5110+02	1.1093+03	1.0053+03	1.0779+03	1.1499+03	1.1193+03
29	8.6922+02	2.8376+02	1.0228+03	1.0959+03	1.1809+03	1.1468+03
30	8.8352+02	3.2000+01	1.0373+03	1.1107+03	1.2026+03	1.1634+03
31	9.2434+02	7.0742+02	1.0832+03	1.1576+03	1.2602+03	1.2149+03
32	8.9788+02	1.1387+03	1.0586+03	1.1341+03	1.2308+03	1.1900+03
33	9.2436+02	2.2476+02	1.0892+03	1.1681+03	1.2844+03	1.2313+03
34	9.5519+02	3.2000+01	1.1158+03	1.1929+03	1.2884+03	1.2494+03
35	9.7627+02	1.1423+03	1.1428+03	1.2202+03	1.3319+03	1.2813+03
36	1.0415+03	1.2878+03	1.1395+03	1.1622+03	1.2470+03	1.1891+03
37	8.5980+02	1.4535+03	1.0291+03	1.1131+03	1.2467+03	1.1836+03
38	8.6038+02	2.3544+02	1.0247+03	1.1103+03	1.2421+03	1.1807+03
39	8.3265+02	3.2000+01	9.9393+02	1.0787+03	1.2051+03	1.1495+03
40	8.1387+02	3.2000+01	9.7111+02	1.0539+03	1.1779+03	1.1225+03

## 300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	660	662	672	680	694	697
	HCOSTU	HCOSTD	WA	QA	DTLMHC	UU HC
1	2.0963+02	8.9227+02	1.7048-01	3.7623+01	9.3936+02	2.0100+01
2	3.9735+02	9.4734+02	1.7054-01	3.9944+01	9.4616+02	2.1186+01
3	5.8412+02	8.8694+02	2.4488-01	5.7833+01	9.6952+02	2.9935+01
4	5.7066+02	9.3625+02	2.4112-01	6.1352+01	1.0148+03	3.0341+01
5	6.8515+02	8.7815+02	2.9543-01	7.0756+01	1.0171+03	3.4912+01
6	5.9025+02	9.5015+02	2.6554-01	7.0344+01	1.0661+03	3.3112+01
7	6.5987+02	9.7249+02	2.5975-01	7.0666+01	1.0753+03	3.2981+01
8	1.3106+03	1.4776+03	1.1551-01	4.1584+01	1.2014+03	1.7371+01
9	1.1563+03	1.4682+03	1.1464-01	3.9842+01	1.1849+03	1.6874+01
10	9.8942+02	1.3790+03	1.8247-01	6.0842+01	1.1726+03	2.6038+01
11	6.5666+02	1.1586+03	2.8370-01	8.3334+01	1.1486+03	3.6408+01
12	1.8461+02	9.7249+02	3.9044-01	9.7949+01	1.1298+03	4.3509+01
13	3.2000+01	9.2634+02	4.1024-01	9.7570+01	1.1227+03	4.3615+01
14	3.2000+01	8.7414+02	2.9586-01	7.1432+01	1.0298+03	3.4811+01
15	3.2000+01	6.8940+02	4.1180-01	7.9038+01	9.7508+02	4.0679+01
16	3.2000+01	6.7167+02	4.1012-01	7.6831+01	9.8025+02	3.9333+01
17	1.4762+02	6.0622+02	7.1442-01	2.0239+02	8.6734+02	1.1710+02
18	3.2000+01	6.0188+02	7.0377-01	1.1172+02	1.0443+03	5.3688+01
19	3.2000+01	5.8117+02	6.9570-01	1.0871+02	1.0322+03	5.2848+01
20	3.2000+01	5.8249+02	7.0471-01	1.0809+02	1.0157+03	5.3406+01
21	3.2000+01	5.0844+02	8.0373-01	1.1157+02	9.5751+02	5.8475+01
22	3.2000+01	5.5851+02	8.1033-01	1.1429+02	9.3408+02	6.1402+01
23	3.2000+01	5.5992+02	8.4195-01	1.1896+02	8.9891+02	6.6415+01
24	3.2000+01	5.5556+02	8.6144-01	1.1646+02	8.0027+02	7.3029+01
25	3.8442+02	4.3206+02	9.0038-01	1.0149+02	6.8904+02	7.3916+01
26	3.2000+01	9.2789+02	2.7991-01	6.1490+01	9.2036+02	3.3529+01
27	3.8965+02	1.0471+03	2.1938-01	5.4950+01	9.7233+02	2.8361+01
28	5.9113+02	1.0782+03	2.1987-01	5.6527+01	9.8429+02	2.8820+01
29	9.5436+01	1.1019+03	2.1286-01	5.6629+01	1.0065+03	2.8234+01
30	4.2626+01	1.1219+03	2.1305-01	5.7800+01	1.0184+03	2.8481+01
31	6.0456+01	1.1729+03	2.1273-01	6.1031+01	1.0628+03	2.8818+01
32	2.6116+02	1.1501+03	2.2272-01	6.2313+01	1.0472+03	2.9861+01
33	7.9508+01	1.1863+03	2.3560-01	6.8814+01	1.1162+03	3.0937+01
34	3.2000+01	1.2116+03	2.1779-01	6.4613+01	1.0903+03	2.9740+01
35	2.9131+02	1.2429+03	2.1532-01	6.5971+01	1.1345+03	2.9183+01
36	1.9709+02	1.1556+03	1.6995-01	5.1162+01	1.0612+03	2.4195+01
37	1.4734+03	1.1268+03	3.0107-01	8.6013+01	1.1704+03	3.6881+01
38	3.2000+01	1.1224+03	2.9962-01	8.5337+01	1.1424+03	3.7487+01
39	6.6044+01	1.0876+03	3.1445-01	8.8678+01	1.1157+03	3.9888+01
40	3.2000+01	1.0622+03	3.1224-01	8.4842+01	1.0931+03	3.8952+01

Table A-3

## 300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	202	203	205	207	209	211
	DATE	TIME	PFMST	PFMMT	SFMST	SFMMT
1	1.2293+01	1.4150+03	1.7362+03	2.0804+02	1.2722+03	1.3380+02
2	1.2293+01	1.5300+03	1.7196+03	2.0540+02	1.2010+03	1.3072+02
3	1.2293+01	1.6200+03	1.7064+03	2.0338+02	1.1431+03	1.2782+02
4	1.2293+01	1.6250+03	1.7022+03	2.0809+02	1.1055+03	1.2505+02
5	1.2293+01	1.8280+03	1.6886+03	1.9665+02	1.0378+03	1.1933+02
6	1.2293+01	2.0000+03	1.6651+03	1.8811+02	8.9316+02	1.0683+02
7	1.2293+01	2.1100+03	1.6847+03	1.8361+02	9.1773+02	9.9572+01
8	1.2293+01	2.2050+03	1.7025+03	1.8302+02	9.8560+02	9.7636+01
9	1.2293+01	2.3000+03	1.7116+03	1.3891+02	1.1621+03	9.8428+01
10	1.2303+01	1.0000+01	1.7519+03	6.8728+01	1.1839+03	1.0173+02
11	1.2303+01	1.0000+02	1.7845+03	1.0314+02	1.2398+03	1.0402+02
12	1.2303+01	2.1000+02	1.7916+03	3.2000+01	1.2942+03	1.0806+02
13	1.2303+01	2.4500+02	1.7978+03	8.3556+01	1.3027+03	1.1040+02
14	1.2303+01	4.0000+02	1.7694+03	1.0138+02	1.2643+03	1.1194+02
15	1.2303+01	5.0500+02	1.7564+03	1.8996+02	1.2098+03	1.0912+02
16	1.2303+01	6.1000+02	1.7477+03	1.8741+02	1.1736+03	1.0569+02
17	1.2303+01	7.1500+02	1.7182+03	1.8474+02	1.1433+03	1.0120+02
18	1.2303+01	8.1500+02	1.7254+03	1.3050+02	9.7077+02	9.4424+01
19	1.2303+01	9.1500+02	1.6935+03	1.7059+02	1.3055+03	9.2092+01
20	1.2303+01	1.1000+03	1.6407+03	1.5017+02	1.5559+03	1.1497+02
21	1.2303+01	1.1050+03	1.6388+03	1.3508+02	1.5540+03	1.1616+02
22	1.2303+01	1.3000+03	1.4080+03	1.1414+02	1.3533+03	1.1854+02
23	1.2303+01	2.0300+03	1.7672+03	9.4380+01	1.4209+03	1.1770+02
24	1.2303+01	2.2150+03	1.7885+03	1.6685+02	1.3292+03	1.1766+02
25	1.2313+01	2.5000+01	1.8151+03	2.2384+02	1.4682+03	1.2012+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	215	219	230	244	252	259
	PFLO	SFLO	PIT-I	PIT	PIT	POT-I
1	6.8892+00	1.9110-01	1.7822+03	1.7789+03	1.7790+03	1.7294+03
2	6.8977+00	1.7516-01	1.7672+03	1.7640+03	1.7647+03	1.7142+03
3	6.9045+00	1.5192-01	1.7536+03	1.7532+03	1.7533+03	1.7011+03
4	6.8691+00	1.4329-01	1.7504+03	1.7488+03	1.7493+03	1.6972+03
5	6.9125+00	1.4421-01	1.7349+03	1.7340+03	1.7343+03	1.6834+03
6	7.0335+00	4.2124-01	1.7170+03	1.7164+03	1.7167+03	1.6599+03
7	6.9687+00	4.0613-01	1.7379+03	1.7370+03	1.7370+03	1.6791+03
8	6.9761+00	4.1204-01	1.7572+03	1.7557+03	1.7557+03	1.6976+03
9	6.9295+00	4.1962-01	1.7589+03	1.7575+03	1.7577+03	1.7066+03
10	2.5154-01	3.9279-01	1.8038+03	1.8013+03	1.8013+03	1.7452+03
11	6.6612+00	4.0576-01	1.8406+03	1.8372+03	1.8375+03	1.7775+03
12	6.3433-02	4.1910-01	1.8466+03	1.8428+03	1.8428+03	1.7851+03
13	6.6417+00	3.8302-01	1.8536+03	1.8497+03	1.8498+03	1.7910+03
14	6.7498+00	4.0941-01	1.8191+03	1.8162+03	1.8163+03	1.7623+03
15	6.8520+00	4.2248-01	1.8059+03	1.8030+03	1.8033+03	1.7500+03
16	6.8422+00	4.4851-01	1.7979+03	1.7954+03	1.7954+03	1.7421+03
17	6.8586+00	5.5841-01	1.7666+03	1.7646+03	1.7651+03	1.7118+03
18	6.7940+00	4.2716-01	1.7806+03	1.7785+03	1.7788+03	1.7195+03
19	6.9201+00	7.4069-01	1.7317+03	1.7305+03	1.7308+03	1.6878+03
20	6.9990+00	1.1642+00	1.6462+03	1.6477+03	1.6478+03	1.6360+03
21	6.9908+00	1.1639+00	1.6439+03	1.6453+03	1.6454+03	1.6335+03
22	6.7973+00	1.3236+00	1.4115+03	1.4171+03	1.4173+03	1.4066+03
23	6.6865+00	1.5361-01	1.7909+03	1.7883+03	1.7886+03	1.7597+03
24	6.7508+00	5.7306-02	1.8082+03	1.8048+03	1.8051+03	1.7811+03
25	6.4157+00	1.2354-01	1.8417+03	1.8371+03	1.8374+03	1.8075+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	267	275	314	324	338	352
	POT	POT	GSBW91	GSBW80	GSBW69	GSBW58
1	1.7210+03	1.7211+03	1.7335+03	1.7400+03	1.7471+03	1.6746+03
2	1.7068+03	1.7071+03	1.7210+03	1.7259+03	1.7322+03	1.6969+03
3	1.6948+03	1.6948+03	1.7088+03	1.7149+03	1.7202+03	1.4759+03
4	1.6908+03	1.6903+03	1.7092+03	1.7112+03	1.7166+03	1.5603+03
5	1.6775+03	1.6773+03	1.6927+03	1.6977+03	1.7015+03	1.7083+03
6	1.6545+03	1.6547+03	1.6869+03	1.6877+03	1.6924+03	1.5390+03
7	1.6730+03	1.6732+03	1.7119+03	1.7055+03	1.7103+03	1.7152+03
8	1.6904+03	1.6906+03	1.7299+03	1.7233+03	1.7295+03	1.7344+03
9	1.6996+03	1.6999+03	1.7247+03	1.7250+03	1.7288+03	1.7346+03
10	1.7366+03	1.7368+03	1.7718+03	1.7635+03	1.7705+03	1.7764+03
11	1.7686+03	1.7687+03	1.8023+03	1.7949+03	1.8020+03	1.6512+03
12	1.7750+03	1.7752+03	1.8022+03	1.8022+03	1.8091+03	1.8177+03
13	1.7809+03	1.7809+03	1.8121+03	1.8077+03	1.8140+03	1.8239+03
14	1.7535+03	1.7535+03	1.7691+03	1.7787+03	1.7858+03	1.7929+03
15	1.7411+03	1.7414+03	1.7618+03	1.7678+03	1.7757+03	1.7813+03
16	1.7329+03	1.7332+03	1.7545+03	1.7612+03	1.7685+03	1.7737+03
17	1.7041+03	1.7042+03	1.7245+03	1.7340+03	1.7412+03	1.7443+03
18	1.7119+03	1.7119+03	1.7398+03	1.7435+03	1.7514+03	1.7553+03
19	1.6815+03	1.6817+03	1.6930+03	1.7064+03	1.7112+03	1.7134+03
20	1.6319+03	1.6321+03	1.6294+03	1.6443+03	1.6414+03	1.4722+03
21	1.6297+03	1.6300+03	1.6283+03	1.6467+03	1.5954+03	1.5168+03
22	1.4079+03	1.4079+03	1.4020+03	1.4085+03	1.4122+03	1.3039+03
23	1.7518+03	1.7518+03	1.7724+03	1.7682+03	1.7717+03	1.6327+03
24	1.7729+03	1.7730+03	1.7976+03	1.7903+03	1.7957+03	1.6418+03
25	1.7970+03	1.7973+03	1.8240+03	1.8157+03	1.8184+03	1.8167+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	362	374	384	392	403	414
	GSBW47	GSBW36	GSBW25	USBW58	USBW47	USBW36
1	1.7614+03	1.7811+03	1.7884+03	1.7558+03	1.7620+03	1.7715+03
2	1.7470+03	1.7647+03	1.7733+03	1.7402+03	1.7476+03	1.7571+03
3	1.7364+03	1.7540+03	1.7618+03	1.7315+03	1.7364+03	1.7449+03
4	1.7320+03	1.7499+03	1.7578+03	1.7271+03	1.7325+03	1.7420+03
5	1.7173+03	1.7346+03	1.7422+03	1.7120+03	1.7175+03	1.7269+03
6	1.7042+03	1.7184+03	1.7248+03	1.6992+03	1.7035+03	1.7107+03
7	1.7240+03	1.7398+03	1.7452+03	1.7183+03	1.7236+03	1.7305+03
8	1.7418+03	1.7581+03	1.7644+03	1.7364+03	1.7420+03	1.7490+03
9	1.7429+03	1.7590+03	1.7659+03	1.7379+03	1.7430+03	1.7511+03
10	1.7841+03	1.8029+03	1.8097+03	1.7761+03	1.7843+03	1.7928+03
11	1.8176+03	1.8378+03	1.8450+03	1.8084+03	1.8175+03	1.8267+03
12	1.8231+03	1.8425+03	1.8500+03	1.8151+03	1.8240+03	1.8325+03
13	1.8291+03	1.8498+03	1.8566+03	1.8221+03	1.8300+03	1.8388+03
14	1.7987+03	1.8208+03	1.8251+03	1.7923+03	1.0479+03	1.8081+03
15	1.7873+03	1.8066+03	1.8129+03	1.7813+03	1.7883+03	1.7965+03
16	1.7807+03	1.8011+03	1.8052+03	1.7729+03	1.7812+03	1.7891+03
17	1.7513+03	1.7694+03	1.7747+03	1.7466+03	1.7518+03	1.7592+03
18	1.7631+03	1.7825+03	1.7877+03	1.7562+03	1.7634+03	1.7713+03
19	1.7213+03	1.7368+03	1.7407+03	1.7176+03	1.7206+03	1.7269+03
20	1.6480+03	1.6574+03	1.6592+03	1.6465+03	1.6458+03	1.6483+03
21	1.6451+03	1.6551+03	1.6566+03	1.6434+03	1.6431+03	1.6456+03
22	1.4185+03	1.4268+03	1.4276+03	1.4204+03	1.4154+03	1.4200+03
23	1.7803+03	1.7927+03	1.7987+03	1.7746+03	1.7795+03	1.7848+03
24	1.8041+03	1.8133+03	1.8169+03	1.7980+03	1.8022+03	1.8043+03
25	1.8300+03	1.8418+03	1.8492+03	1.8227+03	1.8294+03	1.8345+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	424	475	477	479	480	482
	USBW25	SIT-I	SIT	SIT	SOT-I	SOT
1	1.7401+03	1.2787+03	1.2774+03	1.2772+03	1.5023+03	1.5031+03
2	1.7257+03	1.2079+03	1.2070+03	1.2067+03	1.4697+03	1.4708+03
3	1.7138+03	1.1535+03	1.1532+03	1.1532+03	1.4384+03	1.4415+03
4	1.7109+03	1.1134+03	1.1141+03	1.1134+03	1.4289+03	1.4310+03
5	1.6965+03	1.0553+03	1.0558+03	1.0554+03	1.3953+03	1.3979+03
6	1.6800+03	9.0093+02	9.0170+02	9.0151+02	1.4057+03	1.4082+03
7	1.6987+03	9.2271+02	9.2226+02	9.2208+02	1.4134+03	1.4140+03
8	1.7164+03	9.9356+02	9.9208+02	9.9208+02	1.4281+03	1.4285+03
9	1.7191+03	1.1661+03	1.1651+03	1.1648+03	1.4476+03	1.4482+03
10	1.7582+03	1.1914+03	1.1903+03	1.1900+03	1.4690+03	1.4695+03
11	1.7907+03	1.2438+03	1.2428+03	1.2423+03	1.4982+03	1.4989+03
12	1.7958+03	1.3038+03	1.3026+03	1.3021+03	1.5157+03	1.5165+03
13	1.8020+03	1.3103+03	1.3095+03	1.3088+03	1.5174+03	1.5183+03
14	1.7726+03	1.2780+03	1.2769+03	1.2765+03	1.4957+03	1.4966+03
15	1.7604+03	1.2208+03	1.2194+03	1.2190+03	1.4745+03	1.4752+03
16	1.7526+03	1.1842+03	1.1830+03	1.1827+03	1.4629+03	1.4638+03
17	1.7243+03	1.1526+03	1.1525+03	1.1522+03	1.4509+03	1.4531+03
18	1.7361+03	9.7962+02	9.7944+02	9.7926+02	1.4255+03	1.4281+03
19	1.6932+03	1.2996+03	1.2999+03	1.2994+03	1.5147+03	1.5169+03
20	1.6159+03	1.5706+03	1.5710+03	1.5707+03	1.6183+03	1.6193+03
21	1.6136+03	1.5678+03	1.5688+03	1.5683+03	1.6146+03	1.6170+03
22	1.3984+03	1.3648+03	1.3664+03	1.3660+03	1.4035+03	1.4061+03
23	1.7472+03	1.4140+03	1.4126+03	1.4116+03	1.6894+03	1.6926+03
24	1.7636+03	1.3829+03	1.3811+03	1.3806+03	1.7028+03	1.7053+03
25	1.7938+03	1.4611+03	1.4582+03	1.4570+03	1.7423+03	1.7452+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	484	486	488	490	492	494
SOT	BI93	BI80	BI69	BI58	BI47	
1	1.5030+03					
2	1.4703+03					
3	1.4411+03					
4	1.4307+03					
5	1.3974+03					
6	1.4077+03					
7	1.4136+03					
8	1.4280+03					
9	1.4477+03					
10	1.4690+03					
11	1.4986+03					
12	1.5158+03					
13	1.5178+03					
14	1.4959+03					
15	1.4745+03					
16	1.4633+03					
17	1.4526+03					
18	1.4277+03					
19	1.5169+03					
20	1.6188+03					
21	1.6164+03					
22	1.4057+03					
23	1.6921+03					
24	1.7050+03					
25	1.7444+03					

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	496	498	502	505	506	507
	BI36	BI25	BIP	BOP	DP-B	TSAT-I
1			5.7305+01	3.0248+01	2.7057+01	1.7044+03
2			5.5891+01	2.6927+01	2.8964+01	1.6985+03
3			5.3345+01	1.9975+01	3.3370+01	1.6878+03
4			5.2355+01	1.8971+01	3.3384+01	1.6837+03
5			4.9922+01	1.8198+01	3.1724+01	1.6734+03
6			4.9950+01	1.2791+01	3.7159+01	1.6735+03
7			5.2185+01	1.2327+01	3.9858+01	1.6830+03
8			5.5410+01	1.2096+01	4.3314+01	1.6965+03
9			5.4731+01	1.3332+01	4.1400+01	1.6936+03
10			6.0700+01	1.2791+01	4.7909+01	1.7187+03
11			6.6330+01	1.4104+01	5.2226+01	1.7423+03
12			6.7461+01	1.5649+01	5.1812+01	1.7470+03
13			6.8112+01	1.6190+01	5.1922+01	1.7497+03
14			6.3359+01	1.5495+01	4.7865+01	1.7298+03
15			6.0785+01	1.3177+01	4.7608+01	1.7190+03
16			6.0417+01	1.3872+01	4.6545+01	1.7175+03
17			5.7276+01	1.2292+01	4.4984+01	1.7043+03
18			5.7475+01	1.2482+01	4.4993+01	1.7051+03
19			5.5438+01	1.1709+01	4.3729+01	1.6966+03
20			5.6909+01	1.2559+01	4.4350+01	1.7028+03
21			5.6853+01	1.2018+01	4.4834+01	1.7025+03
22			3.1563+01	1.2636+01	1.8926+01	1.5621+03
23			6.5764+01	1.4568+01	5.1196+01	1.7399+03
24			6.2284+01	1.4954+01	4.7331+01	1.7253+03
25			6.2567+01	1.9202+01	4.3365+01	1.7265+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	508	512	521	526	530	537
	DTSC	QSC	QL	QPRI	QFLUX	QUAL-B
1	4.2573+02	1.6497+01	1.1954+01	1.0173+02	2.6908+05	5.9767-01
2	4.9058+02	1.7255+01	1.1577+01	1.0249+02	2.7111+05	6.4880-01
3	5.3433+02	1.6180+01	1.1256+01	1.0117+02	2.6759+05	7.3682-01
4	5.7024+02	1.6208+01	1.1174+01	1.0226+02	2.7049+05	7.8599-01
5	6.1806+02	1.7549+01	1.0869+01	9.9278+01	2.6260+05	7.4532-01
6	7.7259+02	6.3295+01	1.0491+01	1.1382+02	3.0107+05	2.0939-01
7	7.6025+02	6.0239+01	1.1060+01	1.1574+02	3.0614+05	2.3041-01
8	7.0293+02	5.6920+01	1.1573+01	1.1756+02	3.1096+05	2.4381-01
9	5.2757+02	4.4226+01	1.1751+01	1.0090+02	2.6689+05	2.2475-01
10	5.2729+02	4.1652+01	1.2864+01	-8.2394+00	-2.1794+04	-9.1062-02
11	4.9851+02	4.1064+01	1.3815+01	1.1780+02	3.1159+05	2.9395-01
12	4.4319+02	3.8016+01	1.3992+01	-1.2768+01	-3.3774+04	-8.9033-02
13	4.3946+02	3.4491+01	1.4158+01	1.1647+02	3.0808+05	3.2315-01
14	4.5180+02	3.7654+01	1.3237+01	1.0688+02	2.8272+05	2.6662-01
15	4.9827+02	4.2468+01	1.2888+01	1.0704+02	2.8313+05	2.4788-01
16	5.3328+02	4.8058+01	1.2698+01	1.0700+02	2.8303+05	2.2367-01
17	5.5168+02	6.1558+01	1.1932+01	1.0513+02	2.7807+05	1.5793-01
18	7.2552+02	6.0918+01	1.2235+01	1.1729+02	3.1025+05	2.2827-01
19	3.9703+02	5.9692+01	1.1268+01	8.2675+01	2.1868+05	8.4704-02
20	1.3218+02	3.2426+01	9.7318+00	1.2077+01	3.1944+04	6.1932-04
21	1.3469+02	3.3022+01	9.6825+00	1.2668+01	3.3509+04	1.5107-03
22	1.9731+02	5.2469+01	5.5217+00	4.6132+00	1.2202+04	-4.9333-03
23	3.2588+02	1.0390+01	1.2786+01	5.2600+01	1.3913+05	3.6863-01
24	3.4246+02	4.0456+00	1.3308+01	4.4111+01	1.1668+05	9.1247-01
25	2.6544+02	6.8374+00	1.4072+01	5.4566+01	1.4433+05	5.0319-01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	538	542	543	544	548	549
	MFV-B	VVEL-B	DTO-SO	DTO-SI	DTLM-0	U0
1	1.1421-01	5.5015+02	2.7995+02	4.5071+02	3.5858+02	7.5040+02
2	1.1365-01	6.2679+02	2.9756+02	5.0622+02	3.9269+02	6.9038+02
3	1.1194-01	7.0801+02	3.1515+02	5.4762+02	4.2073+02	6.3602+02
4	1.1263-01	7.4101+02	3.2151+02	5.8374+02	4.3967+02	6.1521+02
5	1.0748-01	8.2242+02	3.3958+02	6.2807+02	4.6913+02	5.5976+02
6	8.8205-02	6.4343+02	3.1129+02	7.5892+02	5.0229+02	5.9940+02
7	9.3577-02	6.5890+02	3.2453+02	7.5639+02	5.1036+02	5.9984+02
8	1.0046-01	6.6329+02	3.2914+02	7.0404+02	4.9306+02	6.3067+02
9	9.4310-02	5.7505+02	3.1133+02	5.4057+02	4.1546+02	6.4238+02
10	-3.5768-02	-1.9785+02	3.3481+02	5.5379+02	4.3516+02	-5.0083+01
11	1.1927-01	5.8437+02	3.4242+02	5.3375+02	4.3103+02	7.2288+02
12	-3.7314-02	-1.6991+02	3.3090+02	4.8132+02	4.0142+02	-8.4135+01
13	1.2377-01	5.5987+02	3.3624+02	4.8074+02	4.0419+02	7.6221+02
14	1.0916-01	5.4005+02	3.2338+02	4.8424+02	3.9841+02	7.0961+02
15	1.0472-01	5.6555+02	3.3137+02	5.2925+02	4.2261+02	6.6995+02
16	1.0032-01	5.7044+02	3.3503+02	5.5787+02	4.3702+02	6.4764+02
17	8.8188-02	5.3031+02	3.1569+02	5.5918+02	4.2590+02	6.5290+02
18	9.7506-02	6.5070+02	3.5509+02	7.3991+02	5.2416+02	5.9190+02
19	6.2740-02	2.8684+02	2.1696+02	3.8825+02	2.9434+02	7.4296+02
20	7.2103-04	2.2132+00	2.7853+01	6.5448+01	4.4006+01	7.2590+02
21	1.7583-03	5.4698+00	2.9302+01	6.5659+01	4.5062+01	7.4362+02
22	-6.5298-03	-4.8123+01	8.0160+00	4.1808+01	2.0460+01	5.9641+02
23	5.6623-02	1.3525+02	1.0150+02	3.4565+02	1.9925+02	6.9830+02
24	5.2290-02	1.1935+02	1.0543+02	3.9822+02	2.2031+02	5.2961+02
25	6.2165-02	1.2414+02	9.9319+01	3.4648+02	1.9781+02	7.2965+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	600	603	605	606	608	610
	VCIT-I	VCIT	VCIT	VCOT-I	VCOT	VCOT
1	1.4993+03	1.4981+03	1.4978+03	1.4806+03	1.4795+03	1.4801+03
2	1.4654+03	1.4649+03	1.4641+03	1.4402+03	1.4406+03	1.4413+03
3	1.4326+03	1.4343+03	1.4330+03	1.4012+03	1.3994+03	1.4004+03
4	1.4234+03	1.4243+03	1.4233+03	1.3871+03	1.3860+03	1.3858+03
5	1.3882+03	1.3897+03	1.3888+03	1.3338+03	1.3328+03	1.3328+03
6	1.3971+03	1.3980+03	1.3971+03	1.2680+03	1.2661+03	1.2673+03
7	1.4028+03	1.4037+03	1.4030+03	1.2742+03	1.2725+03	1.2737+03
8	1.4172+03	1.4181+03	1.4172+03	1.2962+03	1.2941+03	1.2953+03
9	1.4392+03	1.4407+03	1.4399+03	1.3771+03	1.3756+03	1.3757+03
10	1.4609+03	1.4618+03	1.4611+03	1.4065+03	1.4051+03	1.4053+03
11	1.4916+03	1.4933+03	1.4922+03	1.4519+03	1.4501+03	1.4502+03
12	1.5088+03	1.5102+03	1.5094+03	1.4687+03	1.4673+03	1.4675+03
13	1.5110+03	1.5123+03	1.5115+03	1.4732+03	1.4726+03	1.4726+03
14	1.4881+03	1.4894+03	1.4888+03	1.4448+03	1.4429+03	1.4431+03
15	1.4665+03	1.4678+03	1.4671+03	1.4142+03	1.4131+03	1.4134+03
16	1.4546+03	1.4559+03	1.4549+03	1.3919+03	1.3901+03	1.3906+03
17	1.4436+03	1.4446+03	1.4440+03	1.3663+03	1.3648+03	1.3652+03
18	1.4169+03	1.4178+03	1.4171+03	1.3103+03	1.3082+03	1.3090+03
19	1.5151+03	1.5172+03	1.5159+03	1.4939+03	1.4940+03	1.4938+03
20	1.6156+03	1.6164+03	1.6153+03	1.6130+03	1.6127+03	1.6131+03
21	1.6127+03	1.6134+03	1.6122+03	1.6097+03	1.6092+03	1.6096+03
22	1.3992+03	1.3991+03	1.3982+03	1.3913+03	1.3898+03	1.3903+03
23	1.6903+03	1.6913+03	1.6903+03	1.6886+03	1.6876+03	1.6878+03
24	1.6993+03	1.7002+03	1.6994+03	1.6961+03	1.6944+03	1.6946+03
25	1.7409+03	1.7420+03	1.7412+03	1.7393+03	1.7387+03	1.7393+03

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	611	613	614	616	618	622
	SP VCO	DP-VC	HCOT-I	HCOT	HCOT	HCAI
1	6.0110+02	5.6664+00	1.3431+03	1.3424+03	1.3401+03	4.7709+01
2	5.8883+02	7.6289+00	1.2845+03	1.2832+03	1.2806+03	4.8560+01
3	5.7704+02	9.4722+00	1.2015+03	1.2021+03	1.2005+03	4.8836+01
4	5.7279+02	1.0957+01	1.1859+03	1.1861+03	1.1848+03	4.3362+01
5	5.5674+02	1.6403+01	9.9899+02	1.0000+03	9.9929+02	3.4714+01
6	5.3696+02	3.8870+01	8.9398+02	8.9377+02	8.9340+02	3.2000+01
7	5.3882+02	3.8728+01	9.4046+02	9.4025+02	9.3952+02	3.2000+01
8	5.4541+02	3.6468+01	1.0114+03	1.0116+03	1.0111+03	3.2000+01
9	5.6979+02	1.8746+01	1.2273+03	1.2261+03	1.2254+03	3.2000+01
10	5.7866+02	1.6446+01	1.2505+03	1.2523+03	1.2513+03	3.2000+01
11	5.9238+02	1.2031+01	1.3258+03	1.3266+03	1.3253+03	3.2000+01
12	5.9747+02	1.2185+01	1.3364+03	1.3356+03	1.3348+03	3.2000+01
13	5.9883+02	1.1471+01	1.3458+03	1.3461+03	1.3440+03	3.2000+01
14	5.9020+02	1.3157+01	1.2799+03	1.2789+03	1.2779+03	3.2000+01
15	5.8097+02	1.5842+01	1.2415+03	1.2418+03	1.2407+03	3.2000+01
16	5.7426+02	1.8930+01	1.2069+03	1.2053+03	1.2046+03	3.2000+01
17	5.6652+02	2.3326+01	1.1642+03	1.1623+03	1.1619+03	3.2000+01
18	5.4966+02	3.2121+01	9.7220+02	9.7123+02	9.7051+02	3.2000+01
19	6.0511+02	6.4348+00	1.4715+03	1.4766+03	1.4751+03	3.4737+01
20	6.4147+02	7.9184-01	1.5990+03	1.5998+03	1.5982+03	1.1760+03
21	6.4047+02	8.9288-01	1.5960+03	1.5972+03	1.5959+03	1.1751+03
22	5.7406+02	2.3822+00	1.3829+03	1.3821+03	1.3814+03	9.9349+02
23	6.6478+02	5.4131-01	1.6455+03	1.6460+03	1.6440+03	6.5164+01
24	6.6710+02	9.9040-01	1.6041+03	1.6016+03	1.6000+03	6.5384+01
25	6.8048+02	4.9556-01	1.7184+03	1.7176+03	1.7144+03	7.3194+01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	624	626	628	630	632	634
	HCAI	HCAO-H	HCO-T	3HA9	9HA9	3HA21
1	4.4949+01	1.0637+03	1.5759+02	1.2063+02	1.3031+02	3.5211+02
2	4.5340+01	1.0064+03	1.5708+02	1.1308+02	1.2276+02	3.3042+02
3	4.6076+01	9.3450+02	1.5646+02	1.0762+02	1.1466+02	3.0638+02
4	4.0602+01	9.2063+02	1.6047+02	1.0195+02	1.0679+02	2.9675+02
5	3.2000+01	7.9159+02	1.6320+02	8.5756+01	8.6636+01	2.5448+02
6	3.2000+01	6.0003+02	1.6399+02	6.7188+01	6.0588+01	1.9995+02
7	3.2000+01	6.4186+02	1.5789+02	6.6814+01	5.9774+01	2.0089+02
8	3.2000+01	7.0538+02	1.5336+02	6.6682+01	6.3602+01	2.1308+02
9	3.2000+01	9.2432+02	1.4758+02	8.4656+01	9.1696+01	2.8560+02
10	3.2000+01	9.3141+02	1.4474+02	8.3578+01	8.8418+01	2.8172+02
11	3.2000+01	9.8392+02	1.4397+02	8.5008+01	9.3368+01	2.9149+02
12	3.2000+01	9.9547+02	1.4441+02	8.5008+01	9.4248+01	2.9785+02
13	3.2000+01	1.0009+03	1.4560+02	8.4436+01	9.4116+01	2.9728+02
14	3.2000+01	9.5991+02	1.4815+02	8.2148+01	8.9628+01	2.8896+02
15	3.2000+01	9.2608+02	1.4846+02	7.8936+01	8.6856+01	2.7594+02
16	3.2000+01	8.8861+02	1.4775+02	7.3832+01	8.0432+01	2.6103+02
17	3.2000+01	8.3671+02	1.4744+02	6.9564+01	7.4404+01	2.5020+02
18	3.2000+01	6.7339+02	1.4830+02	5.5022+01	5.4563+01	2.0186+02
19	3.2000+01	1.2429+03	1.3022+02	1.9522+02	2.2074+02	5.2910+02
20	9.2172+02	5.3090+02	9.4952+01	1.5597+03	1.5478+03	1.5724+03
21	9.2165+02	5.1380+02	9.5326+01	1.5578+03	1.5455+03	1.5706+03
22	7.4621+02	3.1352+02	1.0459+02	1.3306+03	1.3247+03	1.3425+03
23	5.8124+01	1.4753+03	1.3072+02	3.3001+02	3.7196+02	7.5604+02
24	5.8344+01	1.4697+03	1.3094+02	3.3530+02	3.7526+02	7.6374+02
25	6.3514+01	1.5145+03	1.3347+02	3.6459+02	4.0639+02	8.0335+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	636	638	640	642	644	646
	9HA21	3HA33	9HA33	3HA45	3HA57	3HA69
1	2.5371+02	4.5219+02	3.7639+02	4.2463+02	6.6359+02	9.1146+01
2	2.3714+02	4.2134+02	3.5066+02	3.9084+02	6.2096+02	9.1960+01
3	2.1662+02	3.8846+02	3.1920+02	3.5278+02	5.6898+02	9.2664+01
4	2.0919+02	3.7619+02	3.1083+02	3.4178+02	5.5891+02	8.9188+01
5	1.7252+02	3.2025+02	2.5932+02	2.8261+02	4.8464+02	8.3116+01
6	1.2307+02	2.5219+02	1.9203+02	2.1403+02	3.7927+02	7.9508+01
7	1.2665+02	2.5445+02	1.9825+02	2.2025+02	3.8593+02	7.6054+01
8	1.3400+02	2.6972+02	2.0868+02	2.3191+02	4.1193+02	7.5482+01
9	1.9498+02	3.6990+02	2.9750+02	3.3382+02	5.5834+02	7.4536+01
10	1.8994+02	3.6486+02	2.9460+02	3.2764+02	5.5066+02	7.3898+01
11	1.9841+02	3.8125+02	3.0973+02	3.4615+02	5.7585+02	7.7528+01
12	2.0281+02	3.8609+02	3.1545+02	3.5397+02	5.8508+02	7.7528+01
13	2.0224+02	3.9256+02	3.1532+02	3.5429+02	5.8874+02	7.6956+01
14	1.9687+02	3.7487+02	3.0511+02	3.4132+02	5.6859+02	7.7308+01
15	1.8838+02	3.6326+02	2.9296+02	3.2646+02	5.4954+02	7.4096+01
16	1.7752+02	3.4229+02	2.7613+02	3.0559+02	5.2243+02	7.3832+01
17	1.6588+02	3.2495+02	2.5984+02	2.8547+02	4.9572+02	7.2204+01
18	1.2410+02	2.5718+02	2.0010+02	2.1814+02	3.9834+02	6.9982+01
19	4.3098+02	7.2028+02	5.9716+02	7.8218+02	9.6378+02	6.6858+01
20	1.5570+03	1.5452+03	1.4708+03	1.4686+03	1.5698+03	7.7352+01
21	1.5548+03	1.5433+03	1.4690+03	1.4672+03	1.5684+03	7.8606+01
22	1.3264+03	1.3184+03	1.2543+03	1.2653+03	1.3377+03	8.0828+01
23	6.6796+02	9.8316+02	8.2356+02	1.1324+03	1.2292+03	8.2764+01
24	6.7461+02	9.9093+02	8.2950+02	1.1444+03	1.2361+03	8.4304+01
25	7.1063+02	1.0337+03	8.5734+02	1.1950+03	1.2803+03	8.4194+01

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	648 9HA69	650 3HA93	652 9HA93	654 9HA105	656 3HA117	658 9HA117
1	7.4934+02	2.1555+02	9.0464+02	9.8486+02	1.0921+03	1.0491+03
2	6.9992+02	3.2000+01	8.4800+02	9.2852+02	1.0293+03	9.8984+02
3	6.4463+02	3.2000+01	7.8665+02	8.7150+02	9.4809+02	9.2667+02
4	6.2743+02	1.6271+03	7.6951+02	8.5348+02	9.3091+02	9.0907+02
5	5.4140+02	3.2000+01	6.7558+02	7.4840+02	8.1702+02	7.8342+02
6	4.5507+02	1.5095+03	4.9995+02	5.3691+02	5.9579+02	2.1535+02
7	4.8329+02	4.4193+02	5.4401+02	5.8009+02	6.3214+02	3.0121+02
8	4.8712+02	2.9624+02	5.9951+02	6.3411+02	7.0720+02	2.0340+02
9	6.2642+02	7.7730+02	7.7246+02	8.5176+02	9.4423+02	5.5526+02
10	6.2534+02	7.4842+02	7.7006+02	8.5078+02	9.4866+02	4.5606+02
11	6.5525+02	8.4608+02	8.0874+02	8.9206+02	9.9832+02	3.5075+02
12	6.6845+02	5.2613+02	8.2449+02	9.1012+02	1.0084+03	5.7585+02
13	6.6744+02	4.3800+02	8.2392+02	9.0790+02	1.0125+03	5.5372+02
14	6.5195+02	7.1513+02	8.0475+02	8.9059+02	9.7627+02	5.2679+02
15	6.2334+02	6.0449+02	7.7378+02	8.5456+02	9.5137+02	6.6150+02
16	5.9920+02	5.1803+02	7.5046+02	8.2783+02	9.1836+02	4.8239+02
17	5.7580+02	6.8742+02	7.3084+02	7.6616+02	8.5924+02	4.8032+02
18	4.7062+02	5.8414+02	5.8150+02	6.0602+02	6.8740+02	2.3086+02
19	1.0581+03	7.6478+02	1.2073+03	1.2654+03	1.3510+03	3.2000+01
20	1.5610+03	1.3644+03	1.5381+03	1.5056+03	1.5060+03	6.0592+02
21	1.5592+03	1.2674+03	1.5363+03	1.5037+03	1.5037+03	5.8527+02
22	1.3311+03	7.8837+02	1.3159+03	1.2872+03	1.2995+03	4.9731+02
23	1.3253+03	1.1295+03	1.4674+03	1.5149+03	1.5831+03	6.2320+02
24	1.3345+03	1.1679+03	1.4720+03	1.5085+03	1.5635+03	6.0802+02
25	1.3671+03	1.1615+03	1.5093+03	1.5573+03	1.6309+03	5.8809+02

300 KW RESULTS, L-605 TUBE WITH HELICAL INSERT

	660	662	672	680	694	697
	HCOSTU	HCOSTD	WA	QA	DTLMHC	UO HC
1	3.2000+01	9.8484+02	3.2799-01	8.1937+01	1.0434+03	3.9409+01
2	3.2000+01	9.2100+02	3.6395-01	8.5627+01	1.0080+03	4.2628+01
3	3.2000+01	8.4420+02	4.0781-01	8.8452+01	9.6269+02	4.6109+01
4	3.0445+02	8.2933+02	4.0649-01	8.4636+01	9.5228+02	4.4602+01
5	5.5605+02	7.2164+02	4.8564-01	8.1036+01	8.5259+02	4.7699+01
6	3.2000+01	4.1711+02	6.9171-01	8.0985+01	8.2098+02	4.9504+01
7	3.2000+01	4.5533+02	6.5564-01	8.3650+01	8.4276+02	4.9811+01
8	7.8594+02	5.3216+02	5.9766-01	8.5835+01	8.7905+02	4.9002+01
9	3.2000+01	8.2383+02	3.7276-01	7.4527+01	9.8119+02	3.8118+01
10	6.7150+02	8.2581+02	3.9669-01	8.0045+01	1.0077+03	3.9865+01
11	9.7825+02	8.7098+02	3.9316-01	8.4735+01	1.0565+03	4.0248+01
12	8.4824+02	8.8803+02	3.8919-01	8.5059+01	1.0659+03	4.0049+01
13	1.2184+02	8.9152+02	3.9136-01	8.6085+01	1.0719+03	4.0304+01
14	9.8749+02	8.5856+02	3.9181-01	8.1977+01	1.0304+03	3.9927+01
15	7.3040+01	8.2396+02	3.9423-01	7.8999+01	1.0050+03	3.9446+01
16	6.9429+02	7.7850+02	4.1453-01	7.9026+01	9.8529+02	4.0250+01
17	4.1582+02	6.6880+02	4.3434-01	7.6972+01	9.6442+02	4.0053+01
18	3.7438+02	4.9286+02	6.1509-01	8.3366+01	8.7018+02	4.8078+01
19	3.2000+01	1.2910+03	1.0854-01	3.1016+01	1.0898+03	1.4282+01
20	9.3999+02	1.5749+03	0.	-0.	8.7604+02	-0.
21	1.0255+03	1.5725+03	0.	-0.	8.7627+02	-0.
22	1.4059+03	1.3380+03	0.	-0.	8.0316+02	-0.
23	9.1025+02	1.5780+03	7.8740-02	2.8516+01	1.1916+03	1.2010+01
24	1.0711+03	1.5824+03	8.1488-02	2.9380+01	1.1685+03	1.2618+01
25	8.8180+02	1.6184+03	8.1315-02	3.0199+01	1.2414+03	1.2208+01

APPENDIX B

Calculational Procedures used to Reduce Data from the 300 KW Facility

### Physical Properties

The sodium physical properties used in the data reduction are taken from Reference 10 and the potassium physical properties from Reference 11.

### Liquid Metal Flow Rates

Primary and secondary liquid metal flow rates were measured with magnetic flowmeters. The flowmeter constants were determined from the measured magnet strength using the procedure described in Reference 12.

### Boiler Instrument Calibrations

Sufficient liquid data were taken in these runs to allow the sodium heat losses in the boiler to be determined and to allow the sodium and boiler wall thermocouples to be calibrated. The necessary data consist of runs with no potassium in the secondary loop, so that the temperature change in the sodium across the boiler is due to heat losses and thermocouple error only. Heat losses through the boiler insulation are only a function of sodium temperature, thus two runs at different sodium flow rates for the same average sodium temperature will allow both the heat losses and thermocouple errors to be determined if the latter are assumed not to be a function of sodium flow rate.

All sodium thermocouples are calibrated by this method relative to a standard thermocouple, which is the sodium inlet thermocouple labeled PIT-I in these runs. For each of the two sodium flows PFLO<sub>1</sub> and PFLO<sub>2</sub> at a selected average sodium temperature, the heat losses (QL) can be expressed

in terms of the sodium heat capacity (C), the reference inlet temperature PIT-I, and the sodium outlet thermocouple Tmj to be calibrated as follows:

$$QL = (PFLO_1)C (PIT-I_1 - T_1^{mj} - Ej) = (PFLO_2)C (PIT-I_2 - T_2^{mj} - Ej)$$

The error Ej in thermocouple reading Tmj is defined in terms of the calibrated thermocouple reading Tj as follows:

$$Tj = Tmj + Ej$$

The above equations were applied to the sodium thermocouples to obtain their corrections and the sodium heat losses QL for the two temperatures (1490 and 1740°F) at which the necessary data were taken. The resulting values of QL were extrapolated to other temperatures by assuming that heat loss versus temperature difference from sodium to ambient is linear on log-log paper.

The resulting equation, with the temperature difference  $\Delta T$  in °F and QL in Btu/sec is given as follows:

$$QL = 2.063 \left( \frac{\Delta T}{1000} \right)^{3.47}$$

The corrections computed for the sodium inlet and outlet well thermocouples were divided by the respective sodium temperatures to obtain fractional corrections, which were found to be more nearly independent of temperature than the absolute corrections. The fractional errors were expressed as linear functions of average sodium in applying the corrections to boiling runs.

The boiler shell thermocouples were treated similarly, except that the thermocouples at each axial position were averaged and a single correction applied to the average. The corrections for the boiler shell thermocouples were obtained as described above with no secondary fluid in the boiler, in which case, due to heat losses, the boiler shell temperature is lower than the sodium bulk temperature. In boiling, however, the shell temperature is higher than the sodium bulk temperatures due to the fact that heat is being transferred in this latter case from the sodium to the potassium. The absolute magnitude of the corrected values therefore will be higher than the sodium bulk temperature, the difference between corrected wall temperature and sodium bulk temperature being a function of the heat transferred from sodium to potassium. The aim of the calibrations applied to the boiler shell thermocouples is to make these thermocouples internally consistent by correcting for differences in boiler shell thickness and thermocouple sheath thickness and variations in attachment of the thermocouples to the shell wall.

No corrections were applied to the potassium thermocouples for the data presented.

The boiler inlet and outlet pressure gages were calibrated by pressurizing the empty loop with inert gas at various known pressures.

#### Boiler Calculations

The subcooling of the potassium entering the boiler (DTSC) is the difference between the saturation temperature at the measured boiler inlet pressure

and the measured inlet temperature.

$$DTSC = TSAT-I-SIT-I$$

The rate of heat transfer required to remove the inlet subcooling, QSC, is calculated:

$$QSC = (SFLO) C_K (DTSC) \text{ Btu/sec.}$$

The net heat transferred (QPRI) in the boiler is given by the product of the sodium mass flow rate and change in enthalpy less the heat losses, as follows, where POT-I and PIT-I were used to compute the enthalpy change:

$$QPRI = PFLO (\Delta H_{Na}) - QL \text{ Btu/sec.}$$

The average heat flux (QFLUX) in the boiler is obtained by dividing the net heat transferred in the boiler by the boiler tube inside area, which is  $1.361 \text{ ft}^2$  for the data reported.

$$QFLUX = \frac{3600 (QPRI)}{1.361} \text{ Btu/hr-ft}^2$$

The heat required to raise the potassium temperature from SIT-I to SOT-I (QKL) is given as follows, where  $\Delta H_K$  is the enthalpy change of potassium liquid from SIT-I to SOT-I:

$$QKL = SFLO (\Delta H_K) \text{ Btu/sec.}$$

The heat available (QB) for vapor production at the boiler outlet pressure is given by:

$$QB = QPRI - QKL \text{ Btu/sec}$$

The mass flow rate of the potassium vapor leaving the boiler (MFV-B) is given by:

$$MFV-B = QB/Hfg \text{ lbs/sec.}$$

The volumetric vapor flow rate (VFV-B) is given by:

$$VFV-B = MFV-B/\rho_v \text{ ft}^3/\text{sec.}$$

The superficial vapor velocity at the boiler exit (VVEL-B) is given as follows where flow area of boiler ( $A_B$ ) = 0.00417  $\text{ft}^2$ :

$$VVEL-B = VFV-B/A_B$$

The quality of the vapor leaving the boiler (QUAL-B) is the vapor mass flow rate divided by the total potassium mass flow rate as follows:

$$QUAL-B = MFV-B/SFLO$$

The log mean average of the inlet and outlet primary to secondary temperature differences (DTLM-O) was calculated as follows:

$$DTLM-O = \frac{(DTO-SO) - (DTO-SI)}{\log_e \left( \frac{DTO - SO}{DTO - SI} \right)}$$

The overall boiler heat transfer coefficient (UO) was calculated as follows:

$$UO = \frac{3600 (QPRI)}{A (DTLM-O)} \text{ Btu/hr-ft}^2 \text{ }^\circ\text{F}$$

The inside area of the boiler tube, A, is 1.361  $\text{ft}^2$ .

### Vertical Condenser Calculations

The potassium pressure at the exit of the vertical condenser SP-VCO was taken as the vapor pressure of potassium at the average vertical condenser outlet temperature.

The two-phase potassium pressure drop across the vertical condenser (DP-VC) was determined from the difference in potassium vapor pressure across the condenser, determined from the inlet and outlet temperatures.

### Horizontal Condenser Calculations

The air mass flow rate (WA) was determined by means of an orifice in the air line leading to the condenser. The heat transferred to the air, QA, in the horizontal condenser was calculated as the product of the air mass flow rate and the change in enthalpy of the air. The bulk air outlet temperatures (HCOT) were not used to calculate the outlet air enthalpy, as these thermocouples see the hot condenser tube and are subject to a radiation error. The temperature indicated by a thermocouple positioned further down the horizontal condenser air outlet line (HCAO-H) was used for this purpose, since this latter thermocouple is believed to have no radiation error.

The overall logarithmic mean temperature difference in the horizontal condenser (DTLMHC) was calculated from the potassium to air inlet and exit temperature differences as follows:

$$DTLMHC = \frac{\Delta T_{out} - \Delta T_{in}}{\log_e \frac{\Delta T_{out}}{\Delta T_{in}}}$$

The overall heat transfer coefficient in the horizontal condenser (UO HC) was computed as follows, where  $A_c$ , the heat transfer area, is  $7.174 \text{ ft}^2$ .

$$UO\ HC = \frac{3600 (QA)}{A_c (DTLMHC)} \quad \text{Btu/hr ft}^2 {}^\circ\text{F}$$

APPENDIX C  
100 KW Data

100 KW Loop Instrumentation  
Beginning February 1, 1964

TC	Location	Z, Inches
6	Boiler Inlet Well	0
7	" " "	0
8	Pipe Wall Temp.	1 1/4
9	" " "	2 1/8
	Start of Heated Zone	2 1/2
10	Boiler Wall	4 7/16
11	" "	6 3/8
12	" "	8 5/16
13	" "	10 7/16
14	" "	12 3/4
15	" "	14 3/8
16	" "	16 5/16
17	" "	17 1/4
18	" "	18 3/16
19	" "	20 3/16
20	" "	22 5/16
21	" "	24 3/16
22	" "	26 3/8
23	" "	28 11/16
24	" "	30 5/16
25	" "	31
26	" "	31 13/16
27	" "	31 13/16
	End of Heated Zone	32 1/2
30	Boiler Outlet Well	37
31	" " "	37

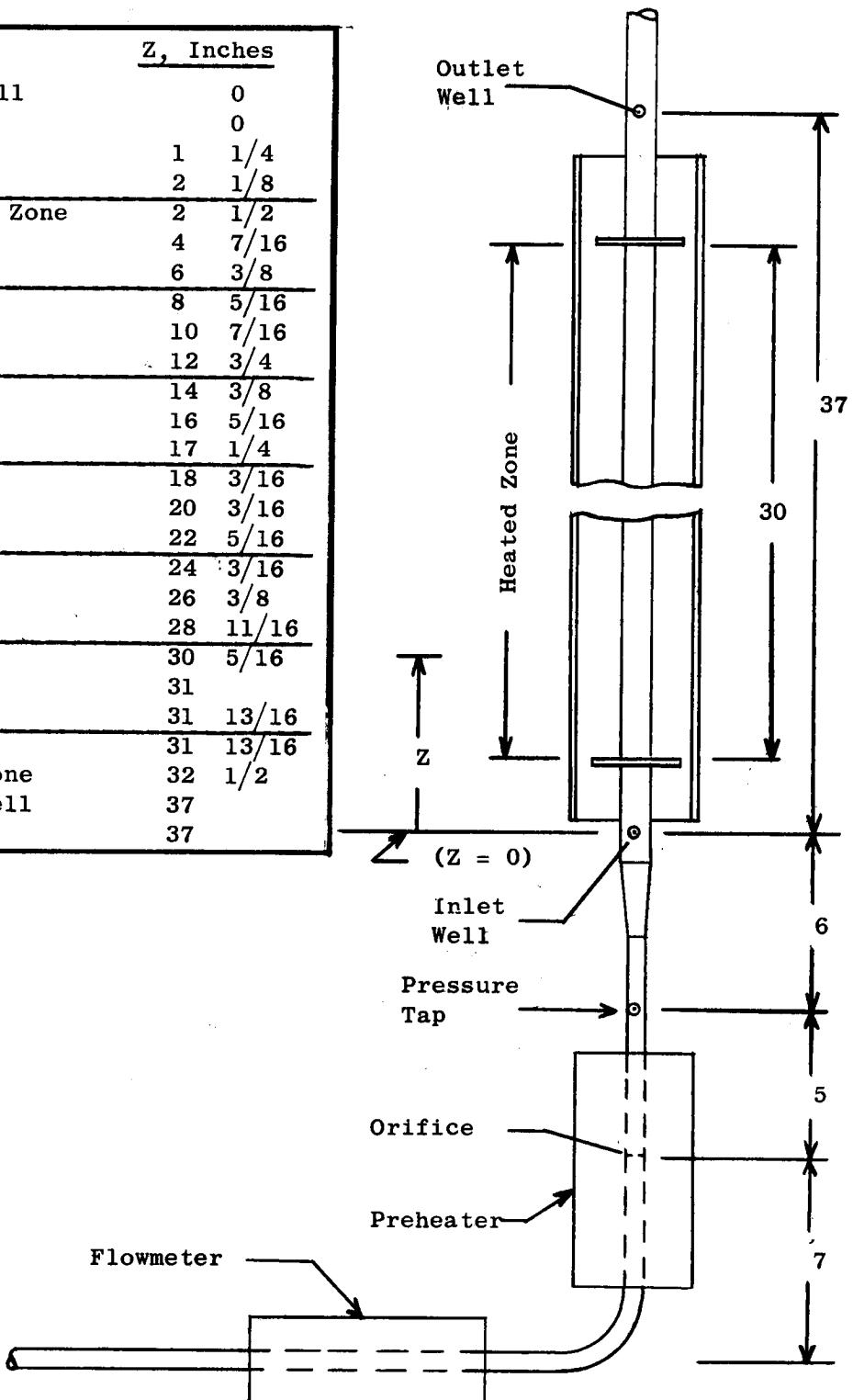


Table C-1  
Schematic Representation of the 100 KW Test Section Showing Thermocouple Locations.

Table C-2

100 KW BOILING POTASSIUM DATA  
Key to Table

<u>Col.</u>	<u>No.</u>	<u>Heading</u>	<u>Description</u>
236		DATE	(e.g., 2.2440 + 03 = 2/24/64)
237		TIME	(e.g., 1.2330 + 03 = 1233)
262		PMPDIS	E.M. Pump Discharge
270		TPH IN	Preheater Inlet Temp., °F
278		TPH IN	" " " "
286		TWO 0	Pipe Wall Temperature at Orifice
294		TB IN	Fluid Temp. at Boiler Inlet
302		TB IN	" " " "
310		TWO 8	Outside Wall Temp. at 8, °F
318		TWO 9	" " " 9, "
326		TWO 10	" " " 10, "
334		TWO 11	" " " 11, "
342		TWO 12	" " " 12, "
350		TWO 13	" " " 13, "
358		TWO 14	" " " 14, "
366		TWO 15	" " " 15, "
374		TWO 16	" " " 16, "
382		TWO 17	" " " 17, "
390		TWO 18	" " " 18, "
398		TWO 19	" " " 19, "
406		TWO 20	" " " 20, "
414		TWO 21	" " " 21, "
422		TWO 22	" " " 22, "
430		TWO 23	" " " 23, "
438		TWO 24	" " " 24, "
446		TWO 25	" " " 25, "
454		TWO 26	" " " 26, "
462		TWO 27	" " " 27, "
470		TB OUT	Fluid Temp. at Boiler Outlet, °F
478		TB OUT	" " " "
509		CND IN	Condenser Inlet Temp., °F
516		CND 37	Condenser Temp. at 37, °F
523		CND 38	" " " 38, °F
530		CND 39	" " " 39, °F
537		CND 40	" " " 40, "
544		CND 41	" " " 41, "
551		CND 42	" " " 42, "
558		CND 43	" " " 43, "
565		CND 44	" " " 44, "
572		CND 45	" " " 45, "
579		CND 46	" " " 46, "
586		CND 47	" " " 47, "
593		CNDDIS	Condenser Outlet Temp., °F

Table C-2  
100 KW BOILING POTASSIUM DATA (continued)  
Key to Table

<u>Col.</u>	<u>No.</u>	<u>Heading</u>	<u>Description</u>				
600		PUMPIN	E.M. Pump Inlet Temp.,	"	"	"	°F
607		TRADTR	Radiation Case Temp.,	"	"	"	°F
614		TRADTL	"	"	"	"	"
621		TRADMR	"	"	"	"	"
628		TRADML	"	"	"	"	"
635		TRADBR	"	"	"	"	"
642		TRADBL	"	"	"	"	"
663		PH CASE	Preheater Case Temp.,	"	"	"	°F
799		QN PH	Net Preheater Power,	KW			
819		QN B	Net Boiler Power,	KW			
823		Q/A	Boiler Heat Flux,	Btu/hr-ft <sup>2</sup>			
839		FLOW	Flow Rate,	lb/sec			
842		G	Mass Velocity,	lb/hr-ft <sup>2</sup>			
853		X OUT	Boiler Outlet Quality				
855		EB OUT	Fluid Enthalpy at Boiler Outlet				
858		VELOUT	Vapor Velocity at Boiler Exit,	ft/sec			
859		P SAT	Saturation Pressure Corresponding to Boiler Outlet temp., psia				
1003		TWI 8	Inside Wall Temp. at 8,	"	"	"	°F
1010		TWI 9	"	"	"	"	9,
1017		TWI 10	"	"	"	"	10,
1024		TWI 11	"	"	"	"	11,
1031		TWI 12	"	"	"	"	12,
1038		TWI 13	"	"	"	"	13,
1045		TWI 14	"	"	"	"	14,
1052		TWI 15	"	"	"	"	15,
1059		TWI 16	"	"	"	"	16,
1066		TWI 17	"	"	"	"	17,
1073		TWI 18	"	"	"	"	18,
1080		TWI 19	"	"	"	"	19,
1087		TWI 20	"	"	"	"	20,
1094		TWI 21	"	"	"	"	21,
1101		TWI 22	"	"	"	"	22,
1108		TWI 23	"	"	"	"	23,
1115		TWI 24	"	"	"	"	24,
1122		TWI 25	"	"	"	"	25,
1129		TWI 26	"	"	"	"	26,
1136		TWI 27	"	"	"	"	27,
1137		DT 27	(TWI 27) - (TB OUT)	ave.	at	27,	°F
1138		H 27	<u>Q/A</u>	<u>BTU</u>	<u>DT 27</u>	<u>hr-ft<sup>2</sup></u>	<u>°F</u>

Table C-3

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	236	237	262	270	278	286
	DATE	TIME	PMPDIS	TPH IN	TPH IN	TWC C
1	2.0740+03	1.3430+03	1.2254+03	1.1688+03	1.2107+03	1.3895+03
2	2.0740+03	1.7000+03	1.2786+03	1.2206+03	1.2620+03	1.4426+03
3	2.1040+03	1.5280+03	1.2317+03	1.1237+03	1.2161+03	1.4950+03
4	2.1140+03	9.0100+02	1.2162+03	1.1326+03	1.2021+03	1.4546+03
5	2.1140+03	1.0350+03	1.2159+03	1.1434+03	1.2013+03	1.4229+03
6	2.1140+03	1.2150+03	1.2139+03	1.1988+03	1.1986+03	1.3889+03
7	2.1140+03	1.3330+03	1.2140+03	1.1527+03	1.1984+03	1.3576+03
8	2.1140+03	1.4350+03	1.2153+03	1.1654+03	1.1992+03	1.3282+03
9	2.1140+03	1.6050+03	1.2154+03	1.1995+03	1.1993+03	1.3002+03
10	2.1240+03	1.0170+03	1.2027+03	1.1696+03	1.1875+03	1.2583+03
11	2.1240+03	1.2170+03	1.2029+03	1.1884+03	1.1881+03	1.2325+03
12	2.1240+03	1.3220+03	1.1964+03	1.1807+03	1.1805+03	1.1961+03
13	2.1240+03	1.4220+03	1.1986+03	1.1834+03	1.1833+03	1.1759+03
14	2.1240+03	1.5430+03	1.2088+03	1.1930+03	1.1928+03	1.1855+03
15	2.1340+03	1.1530+03	1.2345+03	1.2206+03	1.2202+03	1.2641+03
16	2.1340+03	1.3160+03	1.2379+03	1.2234+03	1.2231+03	1.2661+03
17	2.1340+03	1.4430+03	1.2475+03	1.2327+03	1.2324+03	1.2742+03
18	2.1440+03	1.0200+03	1.2640+03	1.2480+03	1.2476+03	1.2891+03
19	2.1440+03	1.2060+03	1.2677+03	1.2509+03	1.2506+03	1.2927+03
20	2.1440+03	1.3550+03	1.2862+03	1.2630+03	1.2692+03	1.3107+03
21	2.1440+03	1.5150+03	1.3201+03	1.2962+03	1.3019+03	1.3425+03
22	2.1740+03	1.3310+03	1.3777+03	1.3588+03	1.3583+03	1.3958+03
23	2.1740+03	1.4510+03	1.4083+03	1.3876+03	1.3872+03	1.4248+03
24	2.1840+03	1.1000+03	1.4745+03	1.4523+03	1.4518+03	1.4867+03
25	2.1840+03	1.2250+03	1.4735+03	1.4512+03	1.4509+03	1.4853+03
26	2.1840+03	1.3090+03	1.4783+03	1.4547+03	1.4544+03	1.4884+03
27	2.1840+03	1.4220+03	1.5264+03	1.5009+03	1.5005+03	1.5343+03
28	2.1840+03	1.5180+03	1.5588+03	1.5316+03	1.5312+03	1.5651+03
29	2.1840+03	1.6150+03	1.5243+03	1.4998+03	1.4996+03	1.5332+03
30	2.1940+03	1.0000+03	1.1714+03	1.1562+03	1.1560+03	1.1973+03
31	2.1940+03	1.1230+03	1.2163+03	1.1994+03	1.1991+03	1.2411+03
32	2.1940+03	1.3060+03	1.2739+03	1.2553+03	1.2550+03	1.2953+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	294	302	310	318	326	334
	TB IN	TB IN	TWO 8	TWO 9	TWO 10	TWO 11
1	1.3765+03	1.3665+03	1.4154+03	1.4404+03	1.5194+03	1.5648+03
2	1.4296+03	1.4193+03	1.4793+03	1.5112+03	1.6155+03	1.6668+03
3	1.4605+03	1.4486+03	1.4917+03	1.5129+03	1.5774+03	1.6084+03
4	1.4289+03	1.4161+03	1.4609+03	1.4836+03	1.5539+03	1.5887+03
5	1.4030+03	1.3889+03	1.4349+03	1.4582+03	1.5299+03	1.5659+03
6	1.3762+03	1.3621+03	1.4087+03	1.4339+03	1.5100+03	1.5480+03
7	1.3518+03	1.3372+03	1.3838+03	1.4109+03	1.4902+03	1.5296+03
8	1.3279+03	1.3129+03	1.3594+03	1.3851+03	1.4661+03	1.5062+03
9	1.3059+03	1.2912+03	1.3365+03	1.3656+03	1.4521+03	1.4936+03
10	1.2720+03	1.2514+03	1.3015+03	1.3313+03	1.4195+03	1.4623+03
11	1.2523+03	1.2315+03	1.2825+03	1.3147+03	1.4098+03	1.4573+03
12	1.2210+03	1.2009+03	1.2511+03	1.2854+03	1.3800+03	1.4287+03
13	1.2051+03	1.1857+03	1.2368+03	1.2712+03	1.3723+03	1.4213+03
14	1.2151+03	1.1954+03	1.2482+03	1.2823+03	1.3861+03	1.4362+03
15	1.2836+03	1.2618+03	1.3210+03	1.3550+03	1.4625+03	1.5133+03
16	1.2857+03	1.2640+03	1.3231+03	1.3579+03	1.4654+03	1.5176+03
17	1.2941+03	1.2730+03	1.3350+03	1.3703+03	1.4827+03	1.5377+03
18	1.3121+03	1.2869+03	1.3521+03	1.3876+03	1.4984+03	1.5552+03
19	1.3179+03	1.2917+03	1.3595+03	1.3979+03	1.5157+03	1.5771+03
20	1.3366+03	1.3133+03	1.3807+03	1.4184+03	1.5396+03	1.6023+03
21	1.3682+03	1.3506+03	1.4163+03	1.4570+03	1.5842+03	1.6490+03
22	1.4172+03	1.3972+03	1.4683+03	1.5096+03	1.6388+03	1.7055+03
23	1.4451+03	1.4272+03	1.4999+03	1.5433+03	1.6861+03	1.7509+03
24	1.5014+03	1.4855+03	1.5615+03	1.6040+03	1.7443+03	1.8052+03
25	1.4977+03	1.4840+03	1.5604+03	1.6055+03	1.7470+03	1.8045+03
26	1.5009+03	1.4875+03	1.5643+03	1.6104+03	1.7595+03	1.8146+03
27	1.5460+03	1.5321+03	1.6141+03	1.6633+03	1.8117+03	1.8679+03
28	1.5765+03	1.5590+03	1.6503+03	1.7009+03	1.8481+03	1.9064+03
29	1.5427+03	1.5274+03	1.6120+03	1.6592+03	1.7987+03	1.8494+03
30	1.2072+03	1.1915+03	1.2502+03	1.2689+03	1.3516+03	1.3848+03
31	1.2577+03	1.2370+03	1.2930+03	1.3263+03	1.4196+03	1.4595+03
32	1.3052+03	1.2905+03	1.3537+03	1.3885+03	1.4954+03	1.5380+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	342	350	358	366	374	382
	TWO 12	TWO 13	TWO 14	TWO 15	TWO 16	TWO 17
1	1.6022+03	1.6470+03	1.7038+03	1.7291+03	1.7692+03	1.8008+03
2	1.7109+03	1.7614+03	1.8242+03	1.8528+03	1.8745+03	1.8080+03
3	1.6354+03	1.6680+03	1.7112+03	1.7309+03	1.7605+03	1.7783+03
4	1.6168+03	1.6526+03	1.6978+03	1.7196+03	1.7535+03	1.7790+03
5	1.5952+03	1.6328+03	1.6802+03	1.7029+03	1.7378+03	1.7616+03
6	1.5784+03	1.6185+03	1.6695+03	1.6926+03	1.7297+03	1.7564+03
7	1.5615+03	1.6047+03	1.6576+03	1.6824+03	1.7205+03	1.7475+03
8	1.5374+03	1.5809+03	1.6352+03	1.6596+03	1.6984+03	1.7305+03
9	1.5255+03	1.5698+03	1.6270+03	1.6526+03	1.6935+03	1.7224+03
10	1.4928+03	1.5371+03	1.5953+03	1.6225+03	1.6643+03	1.6935+03
11	1.4908+03	1.5409+03	1.6035+03	1.6326+03	1.6786+03	1.7112+03
12	1.4649+03	1.5143+03	1.5785+03	1.6080+03	1.6548+03	1.6879+03
13	1.4581+03	1.5082+03	1.5735+03	1.6046+03	1.6533+03	1.7056+03
14	1.4748+03	1.5281+03	1.5958+03	1.6276+03	1.6776+03	1.7110+03
15	1.5518+03	1.6059+03	1.6739+03	1.7054+03	1.7540+03	1.7866+03
16	1.5549+03	1.6086+03	1.6767+03	1.7076+03	1.7553+03	1.7868+03
17	1.5759+03	1.6321+03	1.7023+03	1.7343+03	1.7849+03	1.8179+03
18	1.5938+03	1.6496+03	1.7219+03	1.7520+03	1.8024+03	1.8361+03
19	1.6169+03	1.6768+03	1.7507+03	1.7840+03	1.7453+03	1.8639+03
20	1.6430+03	1.7032+03	1.7790+03	1.8122+03	1.8568+03	1.8105+03
21	1.6910+03	1.7530+03	1.8291+03	1.8632+03	1.8589+03	1.8156+03
22	1.7476+03	1.8064+03	1.8811+03	1.8153+03	1.8200+03	1.8294+03
23	1.7944+03	1.8571+03	1.8314+03	1.8251+03	1.8205+03	1.8334+03
24	1.8460+03	1.8536+03	1.8365+03	1.8242+03	1.8218+03	1.8373+03
25	1.8472+03	1.8815+03	1.8368+03	1.8223+03	1.8189+03	1.8411+03
26	1.8589+03	1.8594+03	1.8391+03	1.8227+03	1.8210+03	1.8471+03
27	1.9087+03	1.8294+03	1.8443+03	1.8254+03	1.8253+03	1.8526+03
28	1.9235+03	1.8748+03	1.8659+03	1.8434+03	1.8364+03	2.0591+03
29	1.8946+03	1.8280+03	1.8387+03	1.8258+03	1.8248+03	1.8541+03
30	1.4167+03	1.4619+03	1.5126+03	1.5379+03	1.5752+03	1.6015+03
31	1.4966+03	1.5484+03	1.6088+03	1.6385+03	1.6816+03	1.7125+03
32	1.5785+03	1.6352+03	1.7011+03	1.7324+03	1.7778+03	1.8124+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	398	406	438	446	462	470
	TWO 19	TWO 20	TWO 24	TWO 25	TWO 27	TB OUT
1	1.8673+03	1.8149+03	1.8031+03	1.8031+03	1.7983+03	1.7513+03
2	1.8244+03	1.8138+03	1.8111+03	1.8106+03	1.8069+03	1.7685+03
3	1.8287+03	1.8366+03	1.7960+03	1.7960+03	1.7926+03	1.7555+03
4	1.8350+03	1.8134+03	1.7985+03	1.7984+03	1.7953+03	1.7573+03
5	1.8187+03	1.8133+03	1.7950+03	1.7947+03	1.7915+03	1.7563+03
6	1.8174+03	1.8170+03	1.7978+03	1.7969+03	1.7941+03	1.7575+03
7	1.8110+03	1.8200+03	1.7984+03	1.7974+03	1.7954+03	1.7580+03
8	1.7950+03	1.8213+03	1.7990+03	1.7990+03	1.7960+03	1.7578+03
9	1.7895+03	1.8169+03	1.8003+03	1.7992+03	1.7959+03	1.7583+03
10	1.7645+03	1.7926+03	1.8003+03	1.8024+03	1.7976+03	1.7570+03
11	1.7879+03	1.8181+03	1.8036+03	1.8055+03	1.8009+03	1.7601+03
12	1.7654+03	1.7960+03	1.8029+03	1.8034+03	1.7997+03	1.7580+03
13	1.7767+03	1.8080+03	1.8035+03	1.8054+03	1.8008+03	1.7584+03
14	1.7931+03	1.8254+03	1.8053+03	1.8069+03	1.8036+03	1.7597+03
15	1.8561+03	1.8083+03	1.8043+03	1.8039+03	1.8014+03	1.7578+03
16	1.8356+03	1.8057+03	1.8012+03	1.8033+03	1.7998+03	1.7560+03
17	1.8139+03	1.8069+03	1.8041+03	1.8057+03	1.8015+03	1.7575+03
18	1.8275+03	1.8174+03	1.8154+03	1.8148+03	1.8127+03	1.7665+03
19	1.8317+03	1.8184+03	1.8159+03	1.8166+03	1.8131+03	1.7669+03
20	1.8248+03	1.8139+03	1.8125+03	1.8107+03	1.8083+03	1.7615+03
21	1.8333+03	1.8209+03	1.8168+03	1.8170+03	1.8142+03	1.7653+03
22	1.8344+03	1.8218+03	1.8165+03	1.8178+03	1.8152+03	1.7626+03
23	1.8365+03	1.8259+03	1.8203+03	1.8205+03	1.8183+03	1.7645+03
24	1.8377+03	1.8284+03	1.8233+03	1.8241+03	1.8207+03	1.7666+03
25	1.8363+03	1.8246+03	1.8203+03	1.8213+03	1.8179+03	1.7639+03
26	1.8394+03	1.8293+03	1.8240+03	1.8245+03	1.8211+03	1.7667+03
27	1.8441+03	1.8306+03	1.8260+03	1.8271+03	1.8226+03	1.7670+03
28	1.8518+03	1.8403+03	1.8351+03	1.8380+03	1.8286+03	1.7694+03
29	1.8416+03	1.8301+03	1.8262+03	1.8267+03	1.8224+03	1.7660+03
30	1.6691+03	1.6969+03	1.7057+03	1.7041+03	1.7019+03	1.6660+03
31	1.7853+03	1.7183+03	1.7192+03	1.7191+03	1.7159+03	1.6719+03
32	1.7302+03	1.7248+03	1.7192+03	1.7194+03	1.7162+03	1.6714+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	478	509	516	523	530	537
	TB OUT	CND IN	CND 37	CND 38	CND 39	CND 40
1	1.7458+03	1.7615+03		1.7552+03	1.1518+03	1.6172+03
2	1.7513+03	1.7665+03		1.7563+03		1.7613+03
3	1.7394+03	1.7592+03	1.7570+03	1.7213+03	1.0891+03	1.5699+03
4	1.7397+03	1.7604+03		1.7234+03		1.5683+03
5	1.7390+03	1.7563+03		1.7178+03		1.5646+03
6	1.7404+03	1.7561+03		1.7218+03		1.5670+03
7	1.7412+03	1.7573+03	1.7556+03	1.7224+03		1.5681+03
8	1.7411+03	1.7566+03	1.7550+03	1.7075+03		1.5573+03
9	1.7418+03	1.7562+03	1.7544+03	1.7133+03		1.5600+03
10	1.7374+03	1.7552+03	1.7536+03	1.6968+03		1.5491+03
11	1.7414+03	1.7573+03	1.7554+03	1.7260+03		1.5710+03
12	1.7397+03	1.7548+03	1.7531+03	1.7109+03		1.5573+03
13	1.7402+03	1.7560+03	1.7538+03	1.7155+03		1.5629+03
14	1.7418+03	1.7576+03	1.7561+03	1.7450+03		1.5883+03
15	1.7395+03	1.7571+03		1.7468+03		1.6580+03
16	1.7381+03	1.7559+03		1.7449+03		1.6601+03
17	1.7397+03	1.7568+03		1.7466+03		1.6995+03
18	1.7487+03	1.7649+03		1.7544+03	1.1598+03	1.7203+03
19	1.7496+03	1.7653+03		1.7544+03		1.7581+03
20	1.7441+03	1.7603+03		1.7488+03		1.7534+03
21	1.7482+03	1.7637+03		1.7520+03		1.7573+03
22	1.7490+03	1.7644+03		1.7518+03		1.7579+03
23	1.7511+03	1.7662+03		1.7522+03		1.7588+03
24	1.7506+03	1.7672+03		1.7541+03		1.7604+03
25	1.7487+03	1.7638+03		1.7507+03		1.7573+03
26	1.7511+03	1.7666+03		1.7529+03		1.7591+03
27	1.7517+03	1.7666+03		1.7523+03		1.7587+03
28	1.7545+03	1.7690+03		1.7541+03		1.7594+03
29	1.7517+03	1.7652+03		1.7512+03		1.7576+03
30	1.6477+03	1.6675+03		1.6144+03		1.4834+03
31	1.6541+03	1.6725+03		1.6644+03		1.6046+03
32	1.6513+03	1.6709+03		1.6629+03		1.6659+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	544	551	558	565	572	579
	CND 41	CND 42	CND 43	CND 44	CND 45	CND 46
1	1.5549+03	1.4967+03	1.4460+03	1.4001+03	1.3628+03	1.3246+03
2	1.7165+03	1.6343+03	1.5658+03	1.5069+03	1.4610+03	1.4138+03
3	1.5130+03	1.4604+03	1.4131+03	1.0819+03	1.3357+03	1.2998+03
4	1.5102+03	1.4581+03	1.4108+03	1.0966+03	1.3328+03	1.2959+03
5	1.5075+03	1.4560+03	1.4086+03		1.3310+03	1.2947+03
6	1.5093+03	1.4571+03	1.4093+03		1.3306+03	1.2946+03
7	1.5104+03	1.4578+03	1.4099+03		1.3318+03	1.2956+03
8	1.5012+03	1.4502+03	1.4034+03		1.3276+03	1.2925+03
9	1.5042+03	1.4529+03	1.4060+03		1.3317+03	1.2968+03
10	1.4951+03	1.4445+03	1.3990+03		1.3240+03	1.2891+03
11	1.5135+03	1.4607+03	1.4126+03		1.3348+03	1.2985+03
12	1.5013+03	1.4499+03	1.4025+03		1.3256+03	1.2901+03
13	1.5061+03	1.4543+03	1.4066+03		1.3296+03	1.2933+03
14	1.5286+03	1.4742+03	1.4251+03		1.3453+03	1.3083+03
15	1.5898+03	1.5274+03	1.4741+03		1.3860+03	1.3456+03
16	1.5907+03	1.5279+03	1.4743+03		1.3879+03	1.3476+03
17	1.6262+03	1.5591+03	1.5012+03		1.4094+03	1.3665+03
18	1.6444+03	1.5761+03	1.5167+03		1.4246+03	1.3816+03
19	1.6861+03	1.6100+03	1.5448+03		1.4462+03	1.4004+03
20	1.7321+03	1.6495+03	1.5797+03		1.4732+03	1.4258+03
21	1.7584+03	1.7340+03	1.6506+03		1.5275+03	1.4762+03
22	1.7577+03	1.7622+03	1.7205+03		1.5793+03	1.5193+03
23	1.7585+03	1.7632+03	1.7632+03		1.6503+03	1.5798+03
24	1.7596+03	1.7644+03	1.7646+03		1.7180+03	1.6405+03
25	1.7570+03	1.7618+03	1.7623+03		1.7255+03	1.6454+03
26	1.7589+03	1.7637+03	1.7645+03		1.7531+03	1.6690+03
27	1.7580+03	1.7633+03	1.7642+03		1.7622+03	1.7574+03
28	1.7591+03	1.7633+03	1.7657+03		1.7625+03	1.7645+03
29	1.7573+03	1.7625+03	1.7629+03		1.7614+03	1.7253+03
30	1.4338+03	1.3868+03	1.3439+03		1.2733+03	1.2397+03
31	1.5404+03	1.4819+03	1.4304+03		1.3464+03	1.3076+03
32	1.6644+03	1.5947+03	1.5299+03		1.4292+03	1.3834+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	586	593	600	607	614	621
	CND 47	CNDDIS	PUMPIN	TRADTR	TRADTL	TRADMIR
1	1.2917+03	1.2466+03	1.1424+03	1.0964+03	1.0960+03	1.0763+03
2	1.3735+03	1.3206+03	1.1970+03	1.1497+03	1.1493+03	1.1365+03
3	1.2679+03	1.2240+03	1.1301+03	1.0412+03	1.0408+03	1.0203+03
4	1.2637+03	1.2193+03	1.1238+03	1.0439+03	1.0435+03	1.0184+03
5	1.2631+03	1.2191+03	1.1243+03	1.0471+03	1.0469+03	1.0214+03
6	1.2629+03	1.2186+03	1.1229+03	1.0539+03	1.0537+03	1.0276+03
7	1.2637+03	1.2193+03	1.1239+03	1.0609+03	1.0606+03	1.0339+03
8	1.2613+03	1.2175+03	1.1232+03	1.0620+03	1.0617+03	1.0345+03
9	1.2651+03	1.2197+03	1.1241+03	1.0685+03	1.0683+03	1.0410+03
10	1.2581+03	1.2152+03	1.1218+03	1.0527+03	1.0525+03	1.0274+03
11	1.2666+03	1.2226+03	1.1258+03	1.0674+03	1.0672+03	1.0423+03
12	1.2582+03	1.2150+03	1.1206+03	1.0649+03	1.0646+03	1.0399+03
13	1.2617+03	1.2179+03	1.1223+03	1.0697+03	1.0695+03	1.0456+03
14	1.2759+03	1.2307+03	1.1323+03	1.0787+03	1.0784+03	1.0555+03
15	1.3103+03	1.2622+03	1.1562+03	1.0752+03	1.0750+03	1.0594+03
16	1.3125+03	1.2639+03	1.1579+03	1.0738+03	1.0736+03	1.0587+03
17	1.3300+03	1.2809+03	1.1694+03	1.0854+03	1.0851+03	1.0708+03
18	1.3448+03	1.2950+03	1.1817+03	1.0816+03	1.0813+03	1.0723+03
19	1.3612+03	1.3083+03	1.1905+03	1.0930+03	1.0927+03	1.0849+03
20	1.3848+03	1.3292+03	1.2072+03	1.1011+03	1.1008+03	1.0951+03
21	1.4308+03	1.3700+03	1.2343+03	1.1228+03	1.1225+03	1.1185+03
22	1.4700+03	1.4039+03	1.2640+03	1.1267+03	1.1264+03	1.1259+03
23	1.5214+03	1.4482+03	1.2957+03	1.1454+03	1.1451+03	1.1451+03
24	1.5773+03	1.4966+03	1.3380+03	1.1576+03	1.1572+03	1.1638+03
25	1.5799+03	1.4982+03	1.3382+03	1.1596+03	1.1592+03	1.1653+03
26	1.5999+03	1.5144+03	1.3468+03	1.1661+03	1.1658+03	1.1725+03
27	1.6784+03	1.5768+03	1.3907+03	1.1818+03	1.1814+03	1.1894+03
28	1.7555+03	1.6384+03	1.4241+03	1.1972+03	1.1968+03	1.2059+03
29	1.6501+03	1.5612+03	1.3808+03	1.1772+03	1.1769+03	1.1842+03
30	1.2101+03	1.1705+03	1.0866+03	9.6553+02	9.6533+02	9.6177+02
31	1.2737+03	1.2276+03	1.1300+03	1.0113+03	1.0110+03	1.0103+03
32	1.3444+03	1.2925+03	1.1806+03	1.0507+03	1.0504+03	1.0521+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	628	635	642	663	799	819
	TRADML	TRADBR	TRADBL	PHCASE	QN PH	QN B
1	1.0966+03	1.0403+03	1.0580+03	1.0362+03	3.1950+00	9.7705+00
2	1.1615+03	1.0978+03	1.1161+03	1.0531+03	3.2495+00	1.2211+01
3	1.0489+03	9.9100+02	1.0036+03	1.1348+03	4.9365+00	7.3994+00
4	1.0507+03	9.9828+02	1.0116+03	1.1073+03	4.4550+00	8.1477+00
5	1.0542+03	1.0020+03	1.0155+03	1.0790+03	3.9225+00	8.5411+00
6	1.0614+03	1.0081+03	1.0221+03	1.0437+03	3.5025+00	8.8916+00
7	1.0682+03	1.0144+03	1.0287+03	1.0081+03	2.9420+00	9.4440+00
8	1.0691+03	1.0150+03	1.0294+03	9.7007+02	2.5030+00	9.7802+00
9	1.0759+03	1.0211+03	1.0360+03	9.2799+02	1.9260+00	1.0165+01
10	1.0588+03	1.0142+03	1.0265+03	8.7083+02	1.4575+00	1.0745+01
11	1.0745+03	1.0275+03	1.0393+03	8.1196+02	1.0026+00	1.1661+01
12	1.0716+03	1.0242+03	1.0357+03	7.2364+02	4.8305-01	1.1920+01
13	1.0774+03	1.0298+03	1.0411+03	6.1507+02	-4.5000-02	1.2325+01
14	1.0873+03	1.0380+03	1.0488+03	6.2090+02	-4.5000-02	1.2908+01
15	1.0871+03	1.0481+03	1.0493+03	8.2117+02	1.0135+00	1.3434+01
16	1.0856+03	1.0464+03	1.0474+03	8.2041+02	9.8100-01	1.3603+01
17	1.0985+03	1.0576+03	1.0585+03	8.2301+02	8.9880-01	1.4051+01
18	1.0963+03	1.0587+03	1.0574+03	8.2798+02	9.5250-01	1.4519+01
19	1.1089+03	1.0697+03	1.0683+03	8.3455+02	9.9540-01	1.5208+01
20	1.1188+03	1.0797+03	1.0779+03	8.3967+02	9.6675-01	1.5748+01
21	1.1413+03	1.1026+03	1.1008+03	8.5044+02	9.9180-01	1.6795+01
22	1.1457+03	1.1026+03	1.1039+03	8.5602+02	9.4900-01	1.7370+01
23	1.1658+03	1.1224+03	1.1235+03	8.6698+02	9.8100-01	1.8358+01
24	1.1784+03	1.1450+03	1.1363+03	8.7941+02	9.8460-01	1.9016+01
25	1.1801+03	1.1484+03	1.1386+03	8.8014+02	9.6320-01	1.9582+01
26	1.1876+03	1.1567+03	1.1468+03	8.7972+02	9.4550-01	1.9614+01
27	1.2045+03	1.1782+03	1.1671+03	8.9328+02	9.6675-01	2.0379+01
28	1.2206+03	1.1991+03	1.1867+03	9.0327+02	9.5600-01	2.1304+01
29	1.1958+03	1.1765+03	1.1640+03	8.9470+02	9.9180-01	2.0243+01
30	9.6268+02	9.4618+02	9.3501+02	7.9722+02	9.5950-01	1.0248+01
31	1.0131+03	9.9313+02	9.8252+02	8.1231+02	9.5950-01	1.1897+01
32	1.0563+03	1.0338+03	1.0224+03	8.2783+02	9.8820-01	1.3953+01

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	823	839	842	853	855	858
	Q/A	FLOW	G	X OUT	EB OUT	VELOUT
1	6.8654+04	6.9879-02	8.3777+04	7.2200-02	4.7864+02	1.2670+01
2	8.5801+04	6.8689-02	8.2350+04	1.3055-01	5.2503+02	2.1519+01
3	5.1993+04	6.9789-02	8.3669+04	5.1960-02	4.6303+02	9.1488+00
4	5.7250+04	6.9064-02	8.2800+04	5.8178-02	4.6797+02	1.0093+01
5	6.0015+04	6.9054-02	8.2787+04	5.8659-02	4.6816+02	1.0211+01
6	6.2478+04	6.9040-02	8.2771+04	5.7717-02	4.6772+02	9.9900+00
7	6.6359+04	6.8993-02	8.2714+04	6.1256-02	4.7053+02	1.0569+01
8	6.8721+04	6.8957-02	8.2671+04	6.1320-02	4.7055+02	1.0580+01
9	7.1425+04	6.8953-02	8.2666+04	6.2584-02	4.7163+02	1.0772+01
10	7.5503+04	6.9204-02	8.2967+04	6.3765-02	4.7196+02	1.1143+01
11	8.1941+04	6.8888-02	8.2588+04	7.5305-02	4.8143+02	1.2913+01
12	8.3759+04	6.8794-02	8.2476+04	7.3081-02	4.7935+02	1.2613+01
13	8.6604+04	6.8780-02	8.2459+04	7.6456-02	4.8202+02	1.3165+01
14	9.0697+04	6.9213-02	8.2978+04	8.7668-02	4.9081+02	1.5105+01
15	9.4397+04	6.9664-02	8.3519+04	1.1308-01	5.0971+02	1.9777+01
16	9.5583+04	6.9242-02	8.3012+04	1.1852-01	5.1354+02	2.0738+01
17	9.8731+04	6.9367-02	8.3163+04	1.2797-01	5.2101+02	2.2286+01
18	1.0202+05	6.9512-02	8.3337+04	1.3777-01	5.3007+02	2.3194+01
19	1.0686+05	6.9262-02	8.3037+04	1.5235-01	5.4122+02	2.5489+01
20	1.1066+05	6.9785-02	8.3664+04	1.6638-01	5.5090+02	2.8662+01
21	1.1801+05	7.0068-02	8.4003+04	1.9192-01	5.7093+02	3.2677+01
22	1.2205+05	7.0100-02	8.4042+04	2.1467-01	5.8801+02	3.6704+01
23	1.2899+05	6.9625-02	8.3472+04	2.4167-01	6.0875+02	4.0716+01
24	1.3362+05	7.1627-02	8.5872+04	2.5907-01	6.2204+02	4.4764+01
25	1.3759+05	7.1294-02	8.5473+04	2.7031-01	6.3022+02	4.6911+01
26	1.3782+05	7.1341-02	8.5529+04	2.7105-01	6.3115+02	4.6588+01
27	1.4319+05	7.1430-02	8.5636+04	2.9593-01	6.5003+02	5.0844+01
28	1.4969+05	6.3554-02	7.6194+04	3.6592-01	7.0328+02	5.5367+01
29	1.4224+05	7.2888-02	8.7384+04	2.8546-01	6.4204+02	5.0141+01
30	7.2005+04	6.9580-02	8.3418+04	6.1828-02	4.5252+02	1.5148+01
31	8.3594+04	6.9556-02	8.3389+04	1.0072-01	4.8413+02	2.4042+01
32	9.8045+04	7.0157-02	8.4110+04	1.4735-01	5.2029+02	3.5721+01

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	859	1003	1010	1017	1024	1031
P SAT	TWI 8	TWI 9	TWI 10	TWI 11	TWI 12	
1	6.6706+01	1.3929+03	1.4179+03	1.4971+03	1.5425+03	1.5800+03
2	6.9511+01	1.4512+03	1.4832+03	1.5877+03	1.6391+03	1.6833+03
3	6.6427+01	1.4747+03	1.4960+03	1.5606+03	1.5916+03	1.6186+03
4	6.6690+01	1.4421+03	1.4649+03	1.5353+03	1.5701+03	1.5983+03
5	6.6479+01	1.4152+03	1.4386+03	1.5104+03	1.5464+03	1.5758+03
6	6.6808+01	1.3882+03	1.4134+03	1.4896+03	1.5277+03	1.5581+03
7	6.6960+01	1.3619+03	1.3892+03	1.4685+03	1.5080+03	1.5400+03
8	6.6927+01	1.3368+03	1.3625+03	1.4436+03	1.4838+03	1.5150+03
9	6.7071+01	1.3129+03	1.3421+03	1.4287+03	1.4703+03	1.5022+03
10	6.6375+01	1.2766+03	1.3064+03	1.3947+03	1.4376+03	1.4682+03
11	6.7241+01	1.2554+03	1.2876+03	1.3829+03	1.4305+03	1.4640+03
12	6.6765+01	1.2233+03	1.2577+03	1.3524+03	1.4012+03	1.4375+03
13	6.6893+01	1.2080+03	1.2425+03	1.3438+03	1.3929+03	1.4297+03
14	6.7236+01	1.2181+03	1.2522+03	1.3563+03	1.4065+03	1.4452+03
15	6.6726+01	1.2898+03	1.3239+03	1.4316+03	1.4825+03	1.5211+03
16	6.6331+01	1.2916+03	1.3264+03	1.4342+03	1.4864+03	1.5238+03
17	6.6722+01	1.3024+03	1.3378+03	1.4505+03	1.5056+03	1.5438+03
18	6.8931+01	1.3185+03	1.3541+03	1.4651+03	1.5220+03	1.5607+03
19	6.9098+01	1.3243+03	1.3628+03	1.4809+03	1.5424+03	1.5823+03
20	6.7751+01	1.3443+03	1.3821+03	1.5036+03	1.5665+03	1.6073+03
21	6.8726+01	1.3776+03	1.4184+03	1.5459+03	1.6109+03	1.6530+03
22	6.8494+01	1.4284+03	1.4698+03	1.5994+03	1.6662+03	1.7084+03
23	6.8989+01	1.4578+03	1.5014+03	1.6445+03	1.7095+03	1.7531+03
24	6.9182+01	1.5181+03	1.5608+03	1.7015+03	1.7625+03	1.8034+03
25	6.8617+01	1.5157+03	1.5609+03	1.7028+03	1.7605+03	1.8033+03
26	6.9261+01	1.5195+03	1.5658+03	1.7153+03	1.7705+03	1.8150+03
27	6.9366+01	1.5677+03	1.6171+03	1.7660+03	1.8223+03	1.8633+03
28	7.0044+01	1.6019+03	1.6527+03	1.8004+03	1.8588+03	1.8760+03
29	6.9247+01	1.5660+03	1.6133+03	1.7532+03	1.8041+03	1.8493+03
30	4.6875+01	1.2263+03	1.2450+03	1.3278+03	1.3612+03	1.3931+03
31	4.8038+01	1.2654+03	1.2987+03	1.3922+03	1.4321+03	1.4694+03
32	4.7716+01	1.3214+03	1.3563+03	1.4634+03	1.5061+03	1.5467+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1038	1045	1052	1059	1066	1080
	TWI 13	TWI 14	TWI 15	TWI 16	TWI 17	TWI 19
1	1.6248+03	1.6817+03	1.7070+03	1.7472+03	1.7789+03	1.8454+03
2	1.7339+03	1.7968+03	1.8255+03	1.8472+03	1.7806+03	1.7970+03
3	1.6512+03	1.6945+03	1.7142+03	1.7438+03	1.7617+03	1.8121+03
4	1.6341+03	1.6794+03	1.7012+03	1.7351+03	1.7607+03	1.8168+03
5	1.6133+03	1.6609+03	1.6836+03	1.7185+03	1.7423+03	1.7995+03
6	1.5982+03	1.6494+03	1.6725+03	1.7096+03	1.7364+03	1.7974+03
7	1.5832+03	1.6362+03	1.6610+03	1.6992+03	1.7262+03	1.7898+03
8	1.5586+03	1.6130+03	1.6374+03	1.6763+03	1.7084+03	1.7731+03
9	1.5466+03	1.6039+03	1.6295+03	1.6705+03	1.6995+03	1.7666+03
10	1.5126+03	1.5708+03	1.5981+03	1.6400+03	1.6691+03	1.7403+03
11	1.5142+03	1.5769+03	1.6061+03	1.6521+03	1.6849+03	1.7617+03
12	1.4870+03	1.5514+03	1.5809+03	1.6277+03	1.6609+03	1.7385+03
13	1.4800+03	1.5454+03	1.5765+03	1.6254+03	1.6778+03	1.7490+03
14	1.4985+03	1.5664+03	1.5983+03	1.6484+03	1.6818+03	1.7641+03
15	1.5753+03	1.6435+03	1.6750+03	1.7237+03	1.7564+03	1.8260+03
16	1.5776+03	1.6459+03	1.6768+03	1.7247+03	1.7562+03	1.8051+03
17	1.6002+03	1.6705+03	1.7026+03	1.7533+03	1.7864+03	1.7824+03
18	1.6167+03	1.6891+03	1.7192+03	1.7698+03	1.8036+03	1.7949+03
19	1.6424+03	1.7164+03	1.7498+03	1.7110+03	1.8299+03	1.7976+03
20	1.6676+03	1.7436+03	1.7769+03	1.8215+03	1.7751+03	1.7895+03
21	1.7151+03	1.7915+03	1.8257+03	1.8213+03	1.7779+03	1.7956+03
22	1.7674+03	1.8423+03	1.7763+03	1.7810+03	1.7904+03	1.7954+03
23	1.8160+03	1.7902+03	1.7840+03	1.7793+03	1.7922+03	1.7953+03
24	1.8110+03	1.7939+03	1.7816+03	1.7791+03	1.7947+03	1.7951+03
25	1.8377+03	1.7930+03	1.7783+03	1.7750+03	1.7973+03	1.7924+03
26	1.8155+03	1.7951+03	1.7787+03	1.7770+03	1.8032+03	1.7954+03
27	1.7837+03	1.7987+03	1.7797+03	1.7796+03	1.8069+03	1.7985+03
28	1.8271+03	1.8182+03	1.7957+03	1.7886+03	2.0120+03	1.8041+03
29	1.7826+03	1.7933+03	1.7804+03	1.7794+03	1.8088+03	1.7962+03
30	1.4383+03	1.4891+03	1.5145+03	1.5518+03	1.5781+03	1.6459+03
31	1.5212+03	1.5817+03	1.6115+03	1.6547+03	1.6856+03	1.7585+03
32	1.6035+03	1.6696+03	1.7009+03	1.7464+03	1.7811+03	1.6987+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1087	1115	1122	1136	1137	1138
	TWI 20	TWI 24	TWI 25	TWI 27	DT 27	H 27
1	1.7930+03	1.7812+03	1.7811+03	1.7764+03	2.7795+01	2.4700+03
2	1.7864+03	1.7837+03	1.7832+03	1.7795+03	1.9553+01	4.3882+03
3	1.8201+03	1.7794+03	1.7793+03	1.7759+03	2.8497+01	1.8245+03
4	1.7952+03	1.7802+03	1.7801+03	1.7770+03	2.8488+01	2.0096+03
5	1.7942+03	1.7758+03	1.7755+03	1.7723+03	2.4616+01	2.4380+03
6	1.7970+03	1.7778+03	1.7769+03	1.7741+03	2.5096+01	2.4895+03
7	1.7988+03	1.7771+03	1.7762+03	1.7742+03	2.4626+01	2.6947+03
8	1.7994+03	1.7770+03	1.7770+03	1.7740+03	2.4530+01	2.8015+03
9	1.7940+03	1.7775+03	1.7763+03	1.7731+03	2.3004+01	3.1049+03
10	1.7684+03	1.7762+03	1.7783+03	1.7735+03	2.6249+01	2.8764+03
11	1.7920+03	1.7774+03	1.7793+03	1.7747+03	2.3974+01	3.4179+03
12	1.7692+03	1.7761+03	1.7766+03	1.7729+03	2.4075+01	3.4791+03
13	1.7803+03	1.7758+03	1.7777+03	1.7731+03	2.3753+01	3.6460+03
14	1.7965+03	1.7763+03	1.7779+03	1.7746+03	2.3902+01	3.7945+03
15	1.7781+03	1.7741+03	1.7737+03	1.7713+03	2.2611+01	4.1749+03
16	1.7752+03	1.7706+03	1.7727+03	1.7693+03	2.2229+01	4.2998+03
17	1.7753+03	1.7725+03	1.7741+03	1.7700+03	2.1328+01	4.6291+03
18	1.7848+03	1.7828+03	1.7822+03	1.7801+03	2.2483+01	4.5377+03
19	1.7843+03	1.7817+03	1.7824+03	1.7789+03	2.0698+01	5.1626+03
20	1.7785+03	1.7772+03	1.7754+03	1.7729+03	2.0145+01	5.4929+03
21	1.7832+03	1.7791+03	1.7793+03	1.7765+03	1.9794+01	5.9621+03
22	1.7829+03	1.7775+03	1.7788+03	1.7762+03	2.0421+01	5.9769+03
23	1.7847+03	1.7791+03	1.7794+03	1.7771+03	1.9342+01	6.6689+03
24	1.7858+03	1.7806+03	1.7814+03	1.7781+03	1.9482+01	6.8583+03
25	1.7806+03	1.7763+03	1.7773+03	1.7739+03	1.7648+01	7.7964+03
26	1.7853+03	1.7800+03	1.7805+03	1.7771+03	1.8221+01	7.5635+03
27	1.7849+03	1.7803+03	1.7814+03	1.7769+03	1.7573+01	8.1483+03
28	1.7926+03	1.7874+03	1.7903+03	1.7808+03	1.8817+01	7.9553+03
29	1.7847+03	1.7808+03	1.7813+03	1.7770+03	1.8178+01	7.8246+03
30	1.6737+03	1.6826+03	1.6809+03	1.6788+03	2.1894+01	3.2887+03
31	1.6914+03	1.6923+03	1.6923+03	1.6890+03	2.5991+01	3.2163+03
32	1.6933+03	1.6877+03	1.6879+03	1.6847+03	2.3303+01	4.2075+03

Table C-4

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	236	237	262	270	278	286
	DATE	TIME	PMPDIS	TPH IN	TPH IN	TWO O
1	2.2440+03	1.2330+03	1.1818+03	1.1676+03	1.1675+03	1.4689+03
2	2.2440+03	1.3360+03	1.1798+03	1.1653+03	1.1651+03	1.4297+03
3	2.2440+03	1.4560+03	1.1802+03	1.1657+03	1.1656+03	1.4007+03
4	2.2540+03	9.1600+02	1.1739+03	1.1591+03	1.1590+03	1.3598+03
5	2.2540+03	1.0420+03	1.1746+03	1.1601+03	1.1600+03	1.3278+03
6	2.2540+03	1.2150+03	1.1730+03	1.1586+03	1.1585+03	1.2962+03
7	2.2540+03	1.3580+03	1.1770+03	1.1618+03	1.1617+03	1.2669+03
8	2.2540+03	1.5110+03	1.1787+03	1.1633+03	1.1632+03	1.2379+03
9	2.2640+03	1.0350+03	1.1679+03	1.1525+03	1.1524+03	1.1970+03
10	2.2640+03	1.2340+03	1.1848+03	1.1693+03	1.1692+03	1.2130+03
11	2.2640+03	1.3410+03	1.2043+03	1.1876+03	1.1875+03	1.2316+03
12	2.2640+03	1.5000+03	1.2226+03	1.2053+03	1.2051+03	1.2488+03
13	2.2740+03	9.3900+02	1.2407+03	1.2232+03	1.2231+03	1.2668+03
14	2.2740+03	1.1310+03	1.2622+03	1.2442+03	1.2440+03	1.2869+03
15	2.2740+03	1.3230+03	1.3528+03	1.3306+03	1.3303+03	1.3710+03
16	2.2740+03	1.4180+03	1.3816+03	1.3590+03	1.3587+03	1.3994+03
17	2.2840+03	1.2280+03	1.1903+03	1.1752+03	1.1751+03	1.4118+03
18	2.2840+03	1.4000+03	1.1806+03	1.1654+03	1.1653+03	1.3674+03
19	2.2840+03	1.5000+03	1.1812+03	1.1659+03	1.1658+03	1.3329+03
20	3.1340+03	1.0150+03	1.1895+03	1.1734+03	1.1732+03	1.3136+03
21	3.1340+03	1.1350+03	1.1893+03	1.1731+03	1.1730+03	1.2896+03
22	3.1340+03	1.2550+03	1.1820+03	1.1658+03	1.1658+03	1.2430+03
23	3.1340+03	1.4150+03	1.1809+03	1.1643+03	1.1643+03	1.2116+03
24	3.1840+03	1.4450+03	1.1781+03	1.1427+03	1.1621+03	1.2007+03
25	3.2040+03	9.3500+02	1.1870+03	1.1710+03	1.1708+03	1.2102+03
26	3.2040+03	1.0540+03	1.1978+03	1.1805+03	1.1803+03	1.2202+03
27	3.2040+03	1.2100+03	1.2165+03	1.1984+03	1.1982+03	1.2385+03
28	3.2040+03	1.3300+03	1.2287+03	1.2106+03	1.2104+03	1.2501+03
29	3.2040+03	1.4550+03	1.2470+03	1.2284+03	1.2282+03	1.2678+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	294	302	310	318	326	334
	TB IN	TB IN	TWO 8	TWO 9	TWO 10	TWO 11
1	1.4380+03	1.4261+03	1.4673+03	1.4895+03	1.5572+03	1.5855+03
2	1.4049+03	1.3918+03	1.4356+03	1.4595+03	1.5319+03	1.5614+03
3	1.3815+03	1.3686+03	1.4145+03	1.4407+03	1.5168+03	1.5492+03
4	1.3496+03	1.3309+03	1.3773+03	1.4029+03	1.4795+03	1.5112+03
5	1.3220+03	1.3039+03	1.3512+03	1.3793+03	1.4608+03	1.4929+03
6	1.2963+03	1.2778+03	1.3276+03	1.3575+03	1.4433+03	1.4791+03
7	1.2740+03	1.2533+03	1.3049+03	1.3358+03	1.4267+03	1.4639+03
8	1.2502+03	1.2282+03	1.2800+03	1.3129+03	1.4056+03	1.4435+03
9	1.2148+03	1.1923+03	1.2468+03	1.2801+03	1.3758+03	1.4183+03
10	1.2320+03	1.2085+03	1.2659+03	1.3002+03	1.4002+03	1.4430+03
11	1.2511+03	1.2274+03	1.2886+03	1.3246+03	1.4347+03	1.4800+03
12	1.2694+03	1.2449+03	1.3096+03	1.3492+03	1.4640+03	1.5129+03
13	1.2902+03	1.2626+03	1.3309+03	1.3721+03	1.4911+03	1.5377+03
14	1.3121+03	1.2827+03	1.3561+03	1.3993+03	1.5232+03	1.5743+03
15	1.4030+03	1.3661+03	1.4549+03	1.5049+03	1.6564+03	1.7190+03
16	1.4295+03	1.3938+03	1.4840+03	1.5362+03	1.6971+03	1.7610+03
17	1.3918+03	1.3770+03	1.4258+03	1.4518+03	1.5352+03	1.5665+03
18	1.3565+03	1.3399+03	1.3908+03	1.4172+03	1.5055+03	1.5383+03
19	1.3277+03	1.3096+03	1.3621+03	1.3909+03	1.4826+03	1.5168+03
20	1.3168+03	1.3057+03	1.3541+03	1.3894+03	1.4867+03	1.5399+03
21	1.2971+03	1.2850+03	1.3337+03	1.3699+03	1.4680+03	1.5219+03
22	1.2578+03	1.2449+03	1.2959+03	1.3350+03	1.4442+03	1.5028+03
23	1.2306+03	1.2177+03	1.2672+03	1.3079+03	1.4144+03	1.4774+03
24	1.2228+03	1.1992+03	1.2696+03	1.3112+03	1.4319+03	1.4861+03
25	1.2280+03	1.2096+03	1.2812+03	1.3225+03	1.4536+03	1.5116+03
26	1.2384+03	1.2201+03	1.2952+03	1.3396+03	1.4768+03	1.5391+03
27	1.2582+03	1.2388+03	1.3171+03	1.3628+03	1.5048+03	1.5713+03
28	1.2753+03	1.2487+03	1.3348+03	1.3841+03	1.5364+03	1.6107+03
29	1.2938+03	1.2667+03	1.3552+03	1.4074+03	1.5712+03	1.6490+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.O. TUBE

	342	350	358	366	374	382
	TWO 12	TWO 13	TWO 14	TWO 15	TWO 16	TWO 17
1	1.6135+03	1.6495+03		1.7091+03	1.7395+03	1.7600+03
2	1.5907+03	1.6297+03	1.6730+03	1.6957+03	1.7275+03	1.7504+03
3	1.5789+03	1.6207+03	1.6669+03	1.6900+03	1.7243+03	1.7486+03
4	1.5391+03	1.5827+03	1.6288+03	1.6536+03	1.6882+03	1.7138+03
5	1.5232+03	1.5668+03	1.6155+03	1.6404+03	1.6759+03	1.7031+03
6	1.5104+03	1.5571+03	1.6097+03	1.6350+03	1.6725+03	1.7006+03
7	1.4976+03	1.5451+03	1.6015+03	1.6285+03	1.6679+03	1.6975+03
8	1.4796+03	1.5283+03	1.5870+03	1.6159+03	1.6565+03	1.6873+03
9	1.4545+03	1.5061+03	1.5669+03	1.5986+03	1.6404+03	1.6715+03
10	1.4807+03	1.5352+03	1.5995+03	1.6317+03	1.6752+03	1.7079+03
11	1.5197+03	1.5785+03	1.6465+03	1.6811+03	1.7292+03	1.7656+03
12	1.5540+03	1.6172+03	1.6902+03	1.7262+03	1.7743+03	1.8122+03
13	1.5841+03	1.6468+03	1.7208+03	1.7582+03	1.8077+03	1.8463+03
14	1.6208+03	1.6867+03	1.7619+03	1.8002+03	1.8500+03	1.8945+03
15	1.7723+03	1.8459+03	1.9256+03	1.9513+03	1.8634+03	1.8988+03
16	1.8145+03	1.8898+03	1.9101+03	1.8667+03	1.8670+03	1.8994+03
17	1.5969+03	1.6368+03	1.6803+03	1.7053+03	1.7400+03	1.7846+03
18	1.5703+03	1.6133+03	1.6602+03	1.6861+03	1.7237+03	1.7511+03
19	1.5511+03	1.5961+03	1.6463+03	1.6742+03	1.7142+03	1.7428+03
20	1.5898+03	1.6498+03	1.6993+03	1.7243+03	1.7675+03	1.7959+03
21	1.5737+03	1.6347+03	1.6846+03	1.7109+03	1.7543+03	1.7823+03
22	1.5601+03	1.6267+03	1.6852+03	1.7124+03	1.7591+03	1.7912+03
23	1.5375+03	1.6066+03	1.6660+03	1.6942+03	1.7425+03	1.7763+03
24	1.5353+03	1.6000+03	1.6628+03	1.6993+03	1.7523+03	1.7864+03
25	1.5643+03	1.6304+03	1.6982+03	1.7357+03	1.7911+03	1.8243+03
26	1.5965+03	1.6659+03	1.7372+03	1.7756+03	1.8316+03	1.8691+03
27	1.6299+03	1.7004+03	1.7714+03	1.8095+03	1.8662+03	1.9045+03
28	1.6720+03	1.7464+03	1.8207+03	1.8589+03	1.9189+03	1.9062+03
29	1.7095+03	1.7853+03	1.8590+03	1.8977+03	1.9449+03	1.9077+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	390	398	406	414	422	430
	TWO 18	TWO 19	TWO 20	TWO 21	TWO 22	TWO 23
1	1.7756+03	1.8096+03	1.8305+03		1.8838+03	1.8369+03
2	1.7680+03	1.8031+03	1.8262+03		1.8835+03	1.8386+03
3	1.7667+03	1.8037+03	1.8288+03		1.8887+03	1.8402+03
4	1.7321+03	1.7707+03	1.7955+03		1.8615+03	1.8511+03
5	1.7217+03	1.7623+03	1.7883+03		1.8493+03	1.8485+03
6	1.7201+03	1.7627+03	1.7910+03		1.8490+03	1.8469+03
7	1.7195+03	1.7650+03	1.7948+03		1.8700+03	1.8506+03
8	1.7098+03	1.7568+03	1.7878+03		1.8661+03	1.8481+03
9	1.6948+03	1.7437+03	1.7754+03		1.8585+03	1.8516+03
10	1.7324+03	1.7827+03	1.8167+03		1.8461+03	1.8372+03
11	1.7904+03	1.8433+03	1.8771+03		1.8524+03	1.8470+03
12	1.8374+03	1.8925+03	1.8626+03		1.8479+03	1.8449+03
13	1.8710+03	1.9046+03	1.8603+03		2.0013+03	1.8484+03
14	1.8869+03	1.8625+03	1.8567+03		2.0242+03	2.1419+03
15	1.8748+03	1.8778+03	1.8692+03		2.1185+03	2.1581+03
16	1.8787+03	1.8816+03	1.8717+03		2.2670+03	1.9805+03
17	1.7989+03	1.8318+03	1.8532+03		1.9099+03	1.8814+03
18	1.7697+03	1.8104+03	1.8364+03		1.9059+03	1.8805+03
19	1.7628+03	1.8060+03	1.8332+03		1.9068+03	1.8811+03
20	1.8246+03	1.8781+03	1.8995+03	1.9255+03	1.8819+03	1.8739+03
21	1.8108+03	1.8655+03	1.8894+03	1.8274+03	1.8832+03	1.8697+03
22	1.8226+03	1.8790+03	1.9057+03	1.9365+03	1.8872+03	1.8814+03
23	1.8085+03	1.8674+03	1.8958+03	1.9061+03	1.8839+03	1.8756+03
24	1.8181+03	1.8811+03	1.9016+03	1.8888+03	1.8894+03	1.8795+03
25	1.8596+03	1.9253+03	1.9014+03	1.8810+03	1.8915+03	1.8822+03
26	1.9035+03	1.9321+03	1.8943+03	1.8822+03	1.8941+03	1.8843+03
27	1.9223+03	1.9160+03	1.8930+03	1.8810+03	1.8957+03	1.8850+03
28	1.8966+03	1.9197+03	1.8981+03	1.8844+03	1.9027+03	1.8880+03
29	1.8947+03	1.9174+03	1.8998+03	1.8836+03	1.9037+03	1.8891+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	438	446	454	462	470	478
	TWO 24	TWO 25	TWO 26	TWO 27	TB OUT	TB OUT
1	1.8345+03	1.8352+03	1.8275+03	1.8319+03	1.7826+03	1.7890+03
2	1.8369+03	1.8368+03	1.8307+03	1.8342+03	1.7839+03	1.7902+03
3	1.8390+03	1.8381+03	1.8315+03	1.8352+03	1.7850+03	1.7913+03
4	1.8203+03	1.7986+03	1.7860+03	1.7691+03	1.7176+03	1.6959+03
5	1.8417+03	1.8424+03	1.8356+03	1.8381+03	1.7944+03	1.7934+03
6	1.8434+03	1.8421+03	1.8366+03	1.8395+03	1.7954+03	1.7942+03
7	1.8457+03	1.8447+03	1.8394+03	1.8437+03	1.7979+03	1.7966+03
8	1.8421+03	1.8422+03	1.8356+03	1.8401+03	1.7940+03	1.7925+03
9	1.8449+03	1.8430+03	1.8379+03	1.8423+03	1.7955+03	1.7951+03
10	1.8408+03	1.8412+03	1.8367+03	1.8394+03	1.7934+03	1.7922+03
11	1.8466+03	1.8467+03	1.8421+03	1.8458+03	1.7977+03	1.7966+03
12	1.8440+03	1.8442+03	1.8401+03	1.8430+03	1.7954+03	1.7938+03
13	1.8480+03	1.8491+03	1.8451+03	1.8485+03	1.7982+03	1.7977+03
14	1.8492+03	1.8504+03	1.8459+03	1.8489+03	1.7981+03	1.7974+03
15	1.8597+03	1.8605+03	1.8545+03	1.8591+03	1.8047+03	1.8015+03
16	1.8621+03	1.8638+03	1.8573+03	1.8615+03	1.8067+03	1.8030+03
17	1.8742+03	1.8738+03	1.8683+03	1.8712+03	1.8331+03	1.8293+03
18	1.8754+03	1.8753+03	1.8696+03	1.8732+03	1.8342+03	1.8306+03
19	1.8771+03	1.8766+03	1.8719+03	1.8749+03	1.8344+03	1.8306+03
20	1.8788+03	1.8772+03	1.8710+03	1.8741+03	1.8348+03	1.8349+03
21	1.8794+03	1.8770+03	1.8706+03	1.8706+03	1.8334+03	1.8337+03
22	1.8837+03	1.8818+03	1.8754+03	1.8777+03	1.8370+03	1.8372+03
23	1.8788+03	1.8774+03	1.8709+03	1.8727+03	1.8316+03	1.8318+03
24	1.8835+03	1.8819+03	1.8772+03	1.8779+03	1.8376+03	1.8364+03
25	1.8846+03	1.8852+03	1.8784+03	1.8798+03	1.8376+03	1.8364+03
26	1.8857+03	1.8871+03	1.8799+03	1.8818+03	1.8384+03	1.8372+03
27	1.8873+03	1.8888+03	1.8816+03	1.8817+03	1.8385+03	1.8376+03
28	1.8908+03	1.8924+03	1.8847+03	1.8854+03	1.8402+03	1.8393+03
29	1.8920+03	1.8937+03	1.8869+03	1.8868+03	1.8408+03	1.8398+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	509	516	523	530	537	544
	CND IN	CND 37	CND 38	CND 39	CND 40	CND 41
1			1.6655+03		1.5208+03	1.4682+03
2			1.6701+03		1.5236+03	1.4709+03
3			1.6736+03		1.5274+03	1.4743+03
4			1.6528+03		1.5110+03	1.4594+03
5			1.6521+03		1.5115+03	1.4601+03
6			1.6576+03		1.5152+03	1.4639+03
7			1.6666+03		1.5219+03	1.4694+03
8			1.6669+03		1.5225+03	1.4694+03
9			1.6593+03		1.5149+03	1.4623+03
10			1.7003+03		1.5478+03	1.4915+03
11			1.7682+03		1.5990+03	1.5371+03
12			1.7856+03		1.6497+03	1.5812+03
13			1.7888+03		1.6866+03	1.6139+03
14			1.7886+03		1.7545+03	1.6702+03
15			1.7919+03		1.7985+03	1.8002+03
16			1.7916+03		1.7989+03	1.8005+03
17			1.6897+03		1.5402+03	1.4901+03
18			1.6859+03		1.5358+03	1.4816+03
19			1.6908+03		1.5387+03	1.4839+03
20	1.8302+03	1.8343+03	1.7460+03	1.6570+03	1.5679+03	1.5115+03
21	1.8284+03	1.8327+03	1.7267+03	1.6427+03	1.5589+03	1.5055+03
22	1.8322+03	1.8366+03	1.7648+03	1.6691+03	1.5781+03	1.5200+03
23	1.8265+03	1.8306+03	1.7649+03	1.6710+03	1.5776+03	1.5183+03
24	1.8328+03	1.8371+03	1.7590+03	1.6648+03	1.5693+03	1.5116+03
25	1.8330+03	1.8370+03	1.8168+03	1.7150+03	1.6100+03	1.5457+03
26	1.8340+03	1.8378+03	1.8190+03	1.7707+03	1.6548+03	1.5844+03
27	1.8346+03	1.8382+03	1.8186+03	1.8194+03	1.6952+03	1.6189+03
28	1.8369+03	1.8406+03	1.8206+03	1.8296+03	1.7762+03	1.6841+03
29	1.8372+03	1.8409+03	1.8195+03	1.8300+03	1.8219+03	1.7352+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	551	558	565	572	579	586
	CND 42	CND 43	CND 44	CND 45	CND 46	CND 47
1	1.4173+03	1.3720+03	1.3311+03	1.2974+03	1.2618+03	1.2310+03
2	1.4200+03	1.3745+03	1.3336+03	1.2997+03	1.2641+03	1.2333+03
3	1.4234+03	1.3774+03	1.3365+03	1.3024+03	1.2664+03	1.2353+03
4	1.4111+03	1.3668+03	1.3268+03	1.2932+03	1.2580+03	1.2273+03
5	1.4115+03	1.3670+03	1.3271+03	1.2937+03	1.2586+03	1.2285+03
6	1.4149+03	1.3700+03	1.3294+03	1.2955+03	1.2594+03	1.2286+03
7	1.4201+03	1.3747+03	1.3338+03	1.3000+03	1.2645+03	1.2339+03
8	1.4200+03	1.3746+03	1.3340+03	1.3003+03	1.2652+03	1.2329+03
9	1.4122+03	1.3669+03	1.3263+03	1.2926+03	1.2572+03	1.2264+03
10	1.4396+03	1.3918+03	1.3492+03	1.3143+03	1.2778+03	1.2462+03
11	1.4805+03	1.4298+03	1.3840+03	1.3465+03	1.3079+03	1.2745+03
12	1.5190+03	1.4663+03	1.4173+03	1.3772+03	1.3365+03	1.3011+03
13	1.5478+03	1.4910+03	1.4409+03	1.3994+03	1.3568+03	1.3209+03
14	1.5967+03	1.5338+03	1.4796+03	1.4364+03	1.3909+03	1.3516+03
15	1.8044+03	1.7563+03	1.6688+03	1.6022+03	1.5372+03	1.4838+03
16	1.8051+03	1.8059+03	1.7408+03	1.6626+03	1.5901+03	1.5291+03
17	1.4363+03	1.3900+03	1.3484+03	1.3140+03	1.2782+03	1.2467+03
18	1.4305+03	1.3836+03	1.3420+03	1.3075+03	1.2718+03	1.2405+03
19	1.4325+03	1.3861+03	1.3445+03	1.3099+03	1.2740+03	1.2424+03
20	1.4580+03	1.4074+03	1.3624+03	1.3252+03	1.2869+03	1.2539+03
21	1.4529+03	1.4033+03	1.3584+03	1.3218+03	1.2838+03	1.2513+03
22	1.4654+03	1.4127+03	1.3652+03	1.3247+03	1.2831+03	1.2496+03
23	1.4624+03	1.4074+03	1.3589+03	1.3205+03	1.2819+03	1.2486+03
24	1.4540+03	1.4013+03	1.3543+03	1.3158+03	1.2769+03	1.2433+03
25	1.4841+03	1.4289+03	1.3795+03		1.2991+03	1.2644+03
26	1.5171+03	1.4589+03	1.4063+03		1.3213+03	1.2846+03
27	1.5478+03	1.4859+03	1.4311+03	1.3865+03	1.3425+03	1.3050+03
28	1.5999+03	1.5291+03	1.4690+03	1.4212+03	1.3732+03	1.3328+03
29	1.6437+03	1.5665+03	1.5017+03	1.4517+03	1.4008+03	1.3577+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	593	600	607	614	621	628
	CNDDIS	PUMPIN	TRADTR	TRADTL	TRADM	TRADML
1	1.1880+03	1.0979+03	9.4388+02	9.4390+02	9.3086+02	9.1082+02
2	1.1899+03	1.1002+03	9.5468+02	9.5474+02	9.4226+02	9.2224+02
3	1.1915+03	1.1011+03	9.6413+02	9.6421+02	9.5219+02	9.3181+02
4	1.1849+03	1.0957+03	9.6402+02	9.6407+02	9.4974+02	9.3081+02
5	1.1857+03	1.0969+03	9.7064+02	9.7072+02	9.5694+02	9.3769+02
6	1.1856+03	1.0967+03	9.8003+02	9.8013+02	9.6717+02	9.4790+02
7	1.1909+03	1.1008+03	9.9241+02	9.9244+02	9.7952+02	9.5991+02
8	1.1916+03	1.1018+03	9.9870+02	9.9874+02	9.8615+02	9.6609+02
9	1.1840+03	1.0942+03	1.0027+03	1.0026+03	9.9049+02	9.6989+02
10	1.2018+03	1.1088+03	1.0193+03	1.0193+03	1.0087+03	9.8765+02
11	1.2275+03	1.1280+03	1.0437+03	1.0438+03	1.0348+03	1.0127+03
12	1.2521+03	1.1449+03	1.0633+03	1.0633+03	1.0567+03	1.0337+03
13	1.2705+03	1.1612+03	1.0783+03	1.0783+03	1.0735+03	1.0500+03
14	1.2983+03	1.1811+03	1.0983+03	1.0983+03	1.0959+03	1.0725+03
15	1.4140+03	1.2683+03	1.1637+03	1.1636+03	1.1656+03	1.1425+03
16	1.4530+03	1.2953+03	1.1805+03	1.1804+03	1.1831+03	1.1598+03
17	1.2032+03	1.1117+03	9.8692+02	9.8689+02	9.7897+02	9.5334+02
18	1.1970+03	1.1065+03	9.9237+02	9.9236+02	9.8432+02	9.5913+02
19	1.1983+03	1.1075+03	1.0021+03	1.0021+03	9.9439+02	9.6876+02
20	1.2075+03	1.1087+03	1.0114+03	1.0114+03	1.0240+03	9.9757+02
21	1.2051+03	1.1077+03	1.0122+03	1.0121+03	1.0245+03	9.9789+02
22	1.2025+03	1.1046+03	1.0300+03	1.0299+03	1.0444+03	1.0166+03
23	1.2016+03	1.1037+03	1.0331+03	1.0331+03	1.0479+03	1.0205+03
24	1.1974+03	1.0974+03	1.0279+03	1.0277+03	1.0377+03	1.0131+03
25	1.2159+03	1.1112+03	1.0481+03	1.0480+03	1.0585+03	1.0342+03
26	1.2343+03	1.1232+03	1.0638+03	1.0636+03	1.0766+03	1.0525+03
27	1.2526+03	1.1377+03	1.0766+03	1.0764+03	1.0911+03	1.0671+03
28	1.2774+03	1.1545+03	1.0980+03	1.0978+03	1.1144+03	1.0906+03
29	1.2993+03	1.1709+03	1.1125+03	1.1124+03	1.1302+03	1.1073+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	635	642	663	799	819	823
	TRADBR	TRADBL	PHCASE	QN PH	QN B	Q/A
1	9.2799+02	9.1376+02	1.1249+03	4.9160+00	8.2695+00	5.8106+04
2	9.3831+02	9.2349+02	1.0928+03	4.4472+00	8.8275+00	6.2027+04
3	9.4747+02	9.3229+02	1.0662+03	3.9100+00	9.1340+00	6.4181+04
4	9.4435+02	9.2673+02	1.0279+03	3.4110+00	9.4484+00	6.6390+04
5	9.5107+02	9.3283+02	9.9280+02	2.9710+00	9.8993+00	6.9558+04
6	9.6022+02	9.4163+02	9.5633+02	2.5030+00	1.0288+01	7.2290+04
7	9.7151+02	9.5238+02	9.1288+02	1.9575+00	1.0794+01	7.5847+04
8	9.7719+02	9.5785+02	8.6180+02	1.4925+00	1.1052+01	7.7659+04
9	9.7908+02	9.5967+02	7.9457+02	9.7020-01	1.1487+01	8.0713+04
10	9.9629+02	9.7650+02	7.9873+02	9.6300-01	1.2177+01	8.5561+04
11	1.0191+03	1.0001+03	8.0600+02	9.3850-01	1.3221+01	9.2902+04
12	1.0423+03	1.0206+03	8.1313+02	9.3850-01	1.4132+01	9.9297+04
13	1.0572+03	1.0351+03	8.1911+02	9.6320-01	1.4742+01	1.0358+05
14	1.0790+03	1.0565+03	8.2743+02	9.8460-01	1.5906+01	1.1176+05
15	1.1491+03	1.1259+03	8.5334+02	9.6320-01	1.9390+01	1.3625+05
16	1.1667+03	1.1428+03	8.6399+02	9.8100-01	2.0465+01	1.4380+05
17	9.6723+02	9.4512+02	1.0704+03	4.0614+00	9.6599+00	6.7876+04
18	9.7137+02	9.4914+02	1.0348+03	3.5950+00	1.0098+01	7.0956+04
19	9.8035+02	9.5764+02	9.9585+02	2.9710+00	1.0862+01	7.6323+04
20	9.4709+02	9.3799+02	9.5764+02	2.3730+00	1.1337+01	7.9662+04
21	9.4687+02	9.3753+02	9.2518+02	2.0700+00	1.1554+01	8.1186+04
22	9.6118+02	9.5157+02	8.6297+02	1.4097+00	1.2170+01	8.5515+04
23	9.6370+02	9.5412+02	8.0361+02	9.1380-01	1.2287+01	8.6338+04
24	9.5440+02	9.5397+02	8.3870+02	9.8095-01	1.2782+01	8.9811+04
25	9.7044+02	9.7041+02	8.4718+02	9.4100-01	1.3541+01	9.5149+04
26	9.8583+02	9.8604+02	8.5272+02	9.4440-01	1.4529+01	1.0209+05
27	9.9872+02	9.9893+02	8.5921+02	9.5120-01	1.5135+01	1.0634+05
28	1.0194+03	1.0200+03	8.6526+02	9.5120-01	1.6172+01	1.1364+05
29	1.0341+03	1.0346+03	8.7045+02	9.4780-01	1.7036+01	1.1971+05

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	839	842	853	855	858	859
	FLOW	G	X OUT	EB OUT	VELOUT	P SAT
1	6.9260-02	8.3035+04	5.2354-02	4.7121+02	7.9030+00	7.6345+01
2	6.9212-02	8.2977+04	5.3446-02	4.7229+02	8.0255+00	7.6701+01
3	6.9031-02	8.2759+04	5.3060-02	4.7223+02	7.9163+00	7.7000+01
4	6.9097-02	8.2839+04	7.1096-02	4.6956+02	1.4275+01	5.6999+01
5	6.9066-02	8.2802+04	4.9200-02	4.7054+02	7.1971+00	7.8601+01
6	6.9047-02	8.2780+04	4.9460-02	4.7091+02	7.2114+00	7.8843+01
7	6.9047-02	8.2779+04	5.2040-02	4.7334+02	7.5246+00	7.9513+01
8	6.9377-02	8.3175+04	5.0609-02	4.7145+02	7.4541+00	7.8413+01
9	6.8935-02	8.2644+04	5.0327-02	4.7166+02	7.3133+00	7.8980+01
10	6.9096-02	8.2837+04	6.7411-02	4.8390+02	9.9039+00	7.8290+01
11	6.9433-02	8.3241+04	8.9099-02	5.0095+02	1.2958+01	7.9496+01
12	6.9451-02	8.3263+04	1.1099-01	5.1678+02	1.6288+01	7.8788+01
13	6.9636-02	8.3486+04	1.2558-01	5.2829+02	1.8268+01	7.9713+01
14	6.9878-02	8.3775+04	1.5133-01	5.4744+02	2.2105+01	7.9657+01
15	7.0000-02	8.3921+04	2.3585-01	6.1124+02	3.3896+01	8.1176+01
16	7.0266-02	8.4241+04	2.6084-01	6.3008+02	3.7409+01	8.1690+01
17	6.9631-02	8.3479+04	5.1789-02	4.8015+02	6.7671+00	8.9542+01
18	6.9540-02	8.3371+04	5.0116-02	4.7916+02	6.5164+00	8.9904+01
19	6.9509-02	8.3333+04	5.6538-02	4.8390+02	7.3459+00	8.9935+01
20	6.9341-02	8.3132+04	6.3269-02	4.8932+02	8.1422+00	9.0656+01
21	6.9673-02	8.3530+04	6.1333-02	4.8764+02	7.9622+00	9.0258+01
22	6.8540-02	8.2172+04	6.5061-02	4.9110+02	8.2198+00	9.1352+01
23	6.8507-02	8.2132+04	6.1808-02	4.8761+02	7.9341+00	8.9691+01
24	6.9654-02	8.3507+04	6.2312-02	4.8906+02	8.0030+00	9.1320+01
25	6.9452-02	8.3265+04	7.9126-02	5.0140+02	1.0132+01	9.1327+01
26	6.9221-02	8.2987+04	1.0089-01	5.1752+02	1.2846+01	9.1564+01
27	6.9729-02	8.3597+04	1.1506-01	5.2796+02	1.4747+01	9.1644+01
28	6.9201-02	8.2963+04	1.3974-01	5.4637+02	1.7683+01	9.2170+01
29	6.9402-02	8.3205+04	1.5962-01	5.6104+02	2.0221+01	9.2335+01

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1003	1010	1017	1024	1031	1038
	TWI 8	TWI 9	TWI 10	TWI 11	TWI 12	TWI 13
1	1.4483+03	1.4705+03	1.5383+03	1.5666+03	1.5946+03	1.6308+03
2	1.4153+03	1.4392+03	1.5117+03	1.5413+03	1.5706+03	1.6096+03
3	1.3934+03	1.4196+03	1.4959+03	1.5283+03	1.5581+03	1.5999+03
4	1.3555+03	1.3811+03	1.4578+03	1.4896+03	1.5175+03	1.5612+03
5	1.3283+03	1.3564+03	1.4380+03	1.4702+03	1.5005+03	1.5442+03
6	1.3037+03	1.3336+03	1.4196+03	1.4555+03	1.4869+03	1.5336+03
7	1.2799+03	1.3108+03	1.4018+03	1.4391+03	1.4729+03	1.5204+03
8	1.2543+03	1.2872+03	1.3801+03	1.4181+03	1.4542+03	1.5030+03
9	1.2201+03	1.2534+03	1.3492+03	1.3918+03	1.4281+03	1.4797+03
10	1.2375+03	1.2719+03	1.3721+03	1.4150+03	1.4528+03	1.5074+03
11	1.2579+03	1.2940+03	1.4043+03	1.4496+03	1.4894+03	1.5484+03
12	1.2768+03	1.3165+03	1.4315+03	1.4805+03	1.5217+03	1.5850+03
13	1.2967+03	1.3380+03	1.4573+03	1.5040+03	1.5505+03	1.6133+03
14	1.3193+03	1.3626+03	1.4868+03	1.5380+03	1.5846+03	1.6507+03
15	1.4104+03	1.4605+03	1.6124+03	1.6752+03	1.7287+03	1.8025+03
16	1.4371+03	1.4894+03	1.6509+03	1.7149+03	1.7685+03	1.8441+03
17	1.4036+03	1.4296+03	1.5131+03	1.5445+03	1.5749+03	1.6149+03
18	1.3675+03	1.3940+03	1.4823+03	1.5152+03	1.5472+03	1.5903+03
19	1.3370+03	1.3659+03	1.4577+03	1.4919+03	1.5263+03	1.5713+03
20	1.3279+03	1.3633+03	1.4607+03	1.5140+03	1.5640+03	1.6241+03
21	1.3069+03	1.3432+03	1.4415+03	1.4955+03	1.5474+03	1.6085+03
22	1.2676+03	1.3068+03	1.4162+03	1.4749+03	1.5324+03	1.5991+03
23	1.2386+03	1.2793+03	1.3861+03	1.4492+03	1.5094+03	1.5787+03
24	1.2398+03	1.2815+03	1.4025+03	1.4567+03	1.5061+03	1.5709+03
25	1.2497+03	1.2911+03	1.4224+03	1.4806+03	1.5334+03	1.5996+03
26	1.2615+03	1.3060+03	1.4434+03	1.5059+03	1.5635+03	1.6330+03
27	1.2820+03	1.3278+03	1.4701+03	1.5367+03	1.5955+03	1.6662+03
28	1.2973+03	1.3467+03	1.4994+03	1.5739+03	1.6353+03	1.7100+03
29	1.3158+03	1.3681+03	1.5323+03	1.6103+03	1.6710+03	1.7470+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1045	1052	1059	1066	1073	1080
	TWI 14	TWI 15	TWI 16	TWI 17	TWI 18	TWI 19
1		1.6905+03	1.7209+03	1.7414+03	1.7569+03	1.7910+03
2	1.6530+03	1.6758+03	1.7075+03	1.7305+03	1.7481+03	1.7833+03
3	1.6462+03	1.6693+03	1.7037+03	1.7280+03	1.7462+03	1.7832+03
4	1.6073+03	1.6322+03	1.6669+03	1.6924+03	1.7107+03	1.7494+03
5	1.5930+03	1.6180+03	1.6535+03	1.6807+03	1.6994+03	1.7400+03
6	1.5862+03	1.6117+03	1.6492+03	1.6774+03	1.6969+03	1.7395+03
7	1.5769+03	1.6040+03	1.6435+03	1.6730+03	1.6951+03	1.7407+03
8	1.5618+03	1.5907+03	1.6314+03	1.6623+03	1.6848+03	1.7319+03
9	1.5407+03	1.5724+03	1.6143+03	1.6455+03	1.6688+03	1.7178+03
10	1.5718+03	1.6040+03	1.6476+03	1.6804+03	1.7049+03	1.7553+03
11	1.6165+03	1.6512+03	1.6994+03	1.7358+03	1.7607+03	1.8137+03
12	1.6582+03	1.6943+03	1.7425+03	1.7805+03	1.8057+03	1.8610+03
13	1.6875+03	1.7250+03	1.7746+03	1.8133+03	1.8380+03	1.8717+03
14	1.7260+03	1.7644+03	1.8144+03	1.8590+03	1.8514+03	1.8269+03
15	1.8824+03	1.9081+03	1.8200+03	1.8555+03	1.8314+03	1.8345+03
16	1.8644+03	1.8209+03	1.8212+03	1.8537+03	1.8329+03	1.8358+03
17	1.6584+03	1.6834+03	1.7183+03	1.7629+03	1.7772+03	1.8101+03
18	1.6373+03	1.6633+03	1.7009+03	1.7283+03	1.7470+03	1.7878+03
19	1.6216+03	1.6495+03	1.6896+03	1.7183+03	1.7383+03	1.7816+03
20	1.6737+03	1.6987+03	1.7420+03	1.7705+03	1.7991+03	1.8528+03
21	1.6585+03	1.6848+03	1.7283+03	1.7563+03	1.7849+03	1.8397+03
22	1.6577+03	1.6849+03	1.7317+03	1.7639+03	1.7953+03	1.8518+03
23	1.6381+03	1.6664+03	1.7148+03	1.7486+03	1.7810+03	1.8399+03
24	1.6338+03	1.6704+03	1.7234+03	1.7577+03	1.7894+03	1.8526+03
25	1.6676+03	1.7051+03	1.7607+03	1.7939+03	1.8293+03	1.8952+03
26	1.7044+03	1.7429+03	1.7991+03	1.8367+03	1.8711+03	1.8998+03
27	1.7374+03	1.7755+03	1.8324+03	1.8707+03	1.8885+03	1.8823+03
28	1.7844+03	1.8227+03	1.8829+03	1.8701+03	1.8605+03	1.8837+03
29	1.8209+03	1.8597+03	1.9070+03	1.8697+03	1.8566+03	1.8794+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1087	1094	1101	1108	1115	1122
	TWI 20	TWI 21	TWI 22	TWI 23	TWI 24	TWI 25
1	1.8120+03		1.8654+03	1.8183+03	1.8160+03	1.8167+03
2	1.8064+03		1.8638+03	1.8188+03	1.8171+03	1.8170+03
3	1.8083+03		1.8683+03	1.8197+03	1.8185+03	1.8176+03
4	1.7743+03		1.8403+03	1.8300+03	1.7991+03	1.7774+03
5	1.7660+03		1.8271+03	1.8263+03	1.8195+03	1.8202+03
6	1.7678+03		1.8260+03	1.8238+03	1.8203+03	1.8191+03
7	1.7706+03		1.8459+03	1.8264+03	1.8215+03	1.8206+03
8	1.7629+03		1.8413+03	1.8233+03	1.8173+03	1.8175+03
9	1.7495+03		1.8328+03	1.8258+03	1.8192+03	1.8172+03
10	1.7894+03		1.8188+03	1.8099+03	1.8135+03	1.8139+03
11	1.8475+03		1.8228+03	1.8174+03	1.8170+03	1.8171+03
12	1.8310+03		1.8163+03	1.8132+03	1.8124+03	1.8125+03
13	1.8273+03		1.9686+03	1.8153+03	1.8149+03	1.8161+03
14	1.8211+03		1.9890+03	2.1070+03	1.8136+03	1.8148+03
15	1.8258+03		2.0758+03	2.1156+03	1.8163+03	1.8171+03
16	1.8259+03		2.2224+03	1.9350+03	1.8163+03	1.8180+03
17	1.8315+03		1.8883+03	1.8598+03	1.8525+03	1.8522+03
18	1.8137+03		1.8834+03	1.8579+03	1.8529+03	1.8527+03
19	1.8088+03		1.8826+03	1.8568+03	1.8528+03	1.8524+03
20	1.8742+03	1.9003+03	1.8565+03	1.8486+03	1.8535+03	1.8519+03
21	1.8635+03	1.8015+03	1.8573+03	1.8439+03	1.8535+03	1.8512+03
22	1.8786+03	1.9094+03	1.8600+03	1.8542+03	1.8565+03	1.8546+03
23	1.8684+03	1.8787+03	1.8564+03	1.8481+03	1.8513+03	1.8499+03
24	1.8731+03	1.8603+03	1.8609+03	1.8510+03	1.8550+03	1.8534+03
25	1.8711+03	1.8507+03	1.8612+03	1.8520+03	1.8544+03	1.8549+03
26	1.8618+03	1.8498+03	1.8617+03	1.8518+03	1.8532+03	1.8547+03
27	1.8592+03	1.8472+03	1.8619+03	1.8512+03	1.8535+03	1.8550+03
28	1.8620+03	1.8482+03	1.8666+03	1.8518+03	1.8547+03	1.8563+03
29	1.8618+03	1.8455+03	1.8657+03	1.8511+03	1.8539+03	1.8556+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1129	1136	1137	1138
	TWI 26	TWI 27	DT 27	H 27
1	1.8089+03	1.8133+03	2.7567+01	2.1078+03
2	1.8109+03	1.8144+03	2.7390+01	2.2646+03
3	1.8110+03	1.8147+03	2.6592+01	2.4136+03
4	1.7648+03	1.7478+03	4.1102+01	1.6153+03
5	1.8134+03	1.8159+03	2.1995+01	3.1624+03
6	1.8135+03	1.8164+03	2.1602+01	3.3465+03
7	1.8152+03	1.8195+03	2.2254+01	3.4082+03
8	1.8109+03	1.8153+03	2.2051+01	3.5218+03
9	1.8122+03	1.8166+03	2.1285+01	3.7921+03
10	1.8094+03	1.8121+03	1.9277+01	4.4384+03
11	1.8125+03	1.8162+03	1.9057+01	4.8750+03
12	1.8084+03	1.8113+03	1.6702+01	5.9453+03
13	1.8120+03	1.8155+03	1.7510+01	5.9156+03
14	1.8103+03	1.8133+03	1.5551+01	7.1867+03
15	1.8111+03	1.8157+03	1.2657+01	1.0764+04
16	1.8115+03	1.8157+03	1.0843+01	1.3262+04
17	1.8467+03	1.8496+03	1.8404+01	3.6880+03
18	1.8470+03	1.8506+03	1.8196+01	3.8996+03
19	1.8476+03	1.8506+03	1.8145+01	4.2064+03
20	1.8456+03	1.8487+03	1.3875+01	5.7412+03
21	1.8448+03	1.8448+03	1.1223+01	7.2341+03
22	1.8482+03	1.8505+03	1.3376+01	6.3933+03
23	1.8434+03	1.8452+03	1.3544+01	6.3745+03
24	1.8486+03	1.8494+03	1.2366+01	7.2625+03
25	1.8481+03	1.8495+03	1.2476+01	7.6264+03
26	1.8474+03	1.8493+03	1.1538+01	8.8480+03
27	1.8478+03	1.8479+03	9.8644+00	1.0781+04
28	1.8486+03	1.8493+03	9.5285+00	1.1926+04
29	1.8489+03	1.8488+03	8.4731+00	1.4128+04

TABLE C-5

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	236	237	262	270	278	286
	DATE	TIME	PMPDIS	TPH IN	TPH IN	TWO O
1	3.2140+03	1.0090+03	1.2661+03	1.2466+03	1.2463+03	1.2856+03
2	3.2140+03	1.1400+03	1.2787+03	1.2585+03	1.2583+03	1.2972+03
3	3.2140+03	1.3080+03	1.3020+03	1.2811+03	1.2809+03	1.3194+03
4	3.2140+03	1.4400+03	1.3119+03	1.2904+03	1.2901+03	1.3288+03
5	3.2240+03	1.0000+03	1.3397+03	1.3181+03	1.3178+03	1.3556+03
6	3.2240+03	1.1350+03	1.3587+03	1.3363+03	1.3360+03	1.3723+03
7	3.2240+03	1.3000+03	1.3779+03	1.3548+03	1.3546+03	1.3907+03
8	3.2240+03	1.4250+03	1.4039+03	1.3790+03	1.3787+03	1.4153+03
9	3.2340+03	9.5000+02	1.1215+03	1.1076+03	1.1074+03	1.4278+03
10	3.2340+03	1.1100+03	1.1227+03	1.1085+03	1.1083+03	1.3984+03
11	3.2340+03	1.2350+03	1.1174+03	1.1030+03	1.1028+03	1.3520+03
12	3.2340+03	1.3500+03	1.1185+03	1.1036+03	1.1035+03	1.3213+03
13	3.2340+03	1.5050+03	1.1201+03	1.1045+03	1.1044+03	1.1048+03
14	3.2440+03	1.1450+03	1.1288+03	1.1123+03	1.1135+03	1.2624+03
15	3.2440+03	1.3000+03	1.1223+03	1.1067+03	1.1075+03	1.2191+03
16	3.2440+03	1.4200+03	1.1222+03	1.1073+03	1.1080+03	1.1876+03
17	3.2540+03	9.5500+02	1.1243+03	1.1086+03	1.1095+03	1.1581+03
18	3.2540+03	1.0150+03	1.1381+03	1.1213+03	1.1223+03	1.1710+03
19	3.2540+03	1.1350+03	1.1579+03	1.1406+03	1.1416+03	1.1903+03
20	3.2540+03	1.3200+03	1.1760+03	1.1581+03	1.1591+03	1.2074+03
21	3.2540+03	1.4450+03	1.1954+03	1.1763+03	1.1776+03	1.2265+03
22	3.2640+03	1.0350+03	1.2149+03	1.1950+03	1.1960+03	1.2440+03
23	3.2640+03	1.2150+03	1.2616+03	1.2412+03	1.2409+03	1.2894+03
24	3.2640+03	1.2350+03	1.2575+03	1.2375+03	1.2372+03	1.2849+03
25	3.2640+03	1.4000+03	1.2994+03	1.2781+03	1.2778+03	1.3245+03
26	3.2740+03	1.0100+03	1.3247+03	1.3027+03	1.3024+03	1.3479+03
27	3.2740+03	1.2100+03	1.3571+03	1.3331+03	1.3329+03	1.3785+03
28	3.2740+03	1.3470+03	1.3857+03	1.3604+03	1.3602+03	1.4052+03
29	3.3040+03	1.0500+03	1.1160+03	1.1002+03	1.0999+03	1.1007+03
30	3.3040+03	1.2250+03	1.1152+03	1.0992+03	1.1001+03	1.3916+03
31	3.3040+03	1.4000+03	1.1176+03	1.1016+03	1.1024+03	1.3589+03
32	3.3040+03	1.4550+03	1.1134+03	1.0974+03	1.0981+03	1.3180+03
33	3.3140+03	1.0200+03	1.1328+03	1.1162+03	1.1173+03	1.3041+03
34	3.3140+03	1.2200+03	1.1366+03	1.1198+03	1.1208+03	1.2758+03
35	3.3140+03	1.3300+03	1.1256+03	1.1093+03	1.1087+03	1.2259+03
36	3.3140+03	1.4450+03	1.1300+03	1.1130+03	1.1137+03	1.1952+03

**100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE**

	<b>294</b>	<b>302</b>	<b>310</b>	<b>318</b>	<b>326</b>	<b>334</b>
	TB IN	TB IN	TWO 8	TWO 9	TWO 10	TWO 11
1	1.3111+03	1.2844+03	1.3761+03	1.4268+03	1.6022+03	1.6863+03
2	1.3223+03	1.2953+03	1.3897+03	1.4409+03	1.6252+03	1.7099+03
3	1.3446+03	1.3186+03	1.4173+03	1.4731+03	1.6671+03	1.7586+03
4	1.3542+03	1.3288+03	1.4297+03	1.4870+03	1.6885+03	1.7805+03
5	1.3798+03	1.3541+03	1.4595+03	1.5156+03	1.7219+03	1.8108+03
6	1.3967+03	1.3719+03	1.4800+03	1.5404+03	1.7556+03	1.8460+03
7	1.4145+03	1.3903+03	1.4996+03	1.5632+03	1.7852+03	1.8734+03
8	1.4381+03	1.4149+03	1.5272+03	1.5945+03	1.8207+03	1.9114+03
9	1.3923+03	1.3852+03	1.4291+03	1.4497+03	1.5258+03	1.5531+03
10	1.3686+03	1.3610+03	1.4076+03	1.4287+03	1.5099+03	1.5401+03
11	1.3288+03	1.3205+03	1.3684+03	1.3900+03	1.4769+03	1.5072+03
12	1.3026+03	1.2943+03	1.3430+03	1.3665+03	1.4579+03	1.4915+03
13	1.2858+03	1.2635+03	1.3147+03	1.3392+03	1.4358+03	1.4712+03
14	1.2557+03	1.2453+03	1.2968+03	1.3238+03	1.4232+03	1.4636+03
15	1.2173+03	1.2066+03	1.2584+03	1.2859+03	1.3852+03	1.4286+03
16	1.1906+03	1.1800+03	1.2320+03	1.2606+03	1.3650+03	1.4075+03
17	1.1644+03	1.1542+03	1.2070+03	1.2368+03	1.3492+03	1.3926+03
18	1.1783+03	1.1678+03	1.2248+03	1.2559+03	1.3754+03	1.4238+03
19	1.2000+03	1.1878+03	1.2483+03	1.2819+03	1.4079+03	1.4594+03
20	1.2185+03	1.2041+03	1.2691+03	1.3060+03	1.4390+03	1.4934+03
21	1.2398+03	1.2233+03	1.2928+03	1.3327+03	1.4731+03	1.5285+03
22	1.2519+03	1.2420+03	1.3121+03	1.3513+03	1.4976+03	1.5555+03
23	1.3007+03	1.2878+03	1.3673+03	1.4135+03	1.5791+03	1.6477+03
24	1.2957+03	1.2832+03	1.3623+03	1.4071+03	1.5714+03	1.6388+03
25	1.3362+03	1.3225+03	1.4109+03	1.4587+03	1.6384+03	1.7105+03
26	1.3599+03	1.3445+03	1.4367+03	1.4879+03	1.6726+03	1.7492+03
27	1.3933+03	1.3747+03	1.4679+03	1.5231+03	1.7163+03	1.7933+03
28	1.4215+03	1.4001+03	1.4975+03	1.5557+03	1.7536+03	1.8291+03
29	1.4301+03	1.3884+03	1.4288+03	1.4481+03	1.5173+03	1.5436+03
30	1.3621+03	1.3560+03	1.3991+03	1.4201+03	1.4946+03	1.5221+03
31	1.3350+03	1.3282+03	1.3740+03	1.3963+03	1.4787+03	1.5096+03
32	1.2989+03	1.2918+03	1.3383+03	1.3612+03	1.4479+03	1.4781+03
33	1.2899+03	1.2818+03	1.3337+03	1.3604+03	1.4577+03	1.4935+03
34	1.2657+03	1.2566+03	1.3095+03	1.3373+03	1.4388+03	1.4760+03
35	1.2217+03	1.2128+03	1.2674+03	1.2984+03	1.4036+03	1.4439+03
36	1.1966+03	1.1866+03	1.2418+03	1.2749+03	1.3855+03	1.4272+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	342	350	358	366	374	382
	TWO 12	TWO 13	TWO 14	TWO 15	TWO 16	TWO 17
1	1.7456+03	1.8236+03	1.8906+03	1.9303+03	1.8979+03	1.9022+03
2	1.7715+03	1.8467+03	1.9159+03	1.9102+03	1.8892+03	1.9038+03
3	1.8196+03	1.8955+03	1.9185+03	1.8836+03	1.8912+03	1.9078+03
4	1.8430+03	1.9156+03	1.8966+03	1.8948+03	1.8946+03	1.9052+03
5	1.8728+03	1.9384+03	1.9050+03	1.8923+03	1.8912+03	1.9006+03
6	1.9070+03	1.9298+03	1.9078+03	1.8955+03	1.8967+03	1.9042+03
7	1.9288+03	1.9124+03	1.9088+03	1.8963+03	1.8970+03	1.9094+03
8	1.9616+03	1.9113+03	1.9088+03	1.8984+03	1.9014+03	1.9168+03
9	1.5713+03	1.6008+03	1.6269+03	1.6456+03	1.6744+03	1.6934+03
10	1.5595+03	1.5919+03	1.6210+03	1.6407+03	1.6713+03	1.6933+03
11	1.5286+03	1.5613+03	1.5931+03	1.6133+03	1.6452+03	1.6675+03
12	1.5138+03	1.5469+03	1.5820+03	1.6021+03	1.6363+03	1.6588+03
13	1.4963+03	1.5302+03	1.5680+03	1.5886+03	1.6245+03	1.6485+03
14	1.4870+03	1.5252+03	1.5648+03	1.5871+03	1.6263+03	1.6525+03
15	1.4536+03	1.4924+03	1.5342+03	1.5564+03	1.5960+03	1.6227+03
16	1.4343+03	1.4749+03	1.5180+03	1.5414+03	1.5831+03	1.6086+03
17	1.4197+03	1.4625+03	1.5075+03	1.5322+03	1.5766+03	1.6032+03
18	1.4532+03	1.4987+03	1.5478+03	1.5745+03	1.6222+03	1.6509+03
19	1.4905+03	1.5386+03	1.5890+03	1.6190+03	1.6683+03	1.6986+03
20	1.5245+03	1.5762+03	1.6308+03	1.6604+03	1.7131+03	1.7442+03
21	1.5642+03	1.6194+03	1.6763+03	1.7083+03	1.7625+03	1.7952+03
22	1.5918+03	1.6476+03	1.7048+03	1.7397+03	1.7948+03	1.8284+03
23	1.6884+03	1.7509+03	1.8136+03	1.8356+03	1.7723+03	1.7826+03
24	1.6791+03	1.7407+03	1.8032+03	1.8256+03	1.7688+03	1.7762+03
25	1.7514+03	1.8144+03	1.7880+03	1.7708+03	1.7693+03	1.7797+03
26	1.7906+03	1.7907+03	1.7747+03	1.7689+03	1.7729+03	1.7862+03
27	1.8321+03	1.7763+03	1.7807+03	1.7720+03	1.7723+03	1.7862+03
28	1.8085+03	1.7822+03	1.7838+03	1.7729+03	1.7768+03	1.7943+03
29	1.5602+03	1.5896+03	1.6127+03	1.6305+03	1.6573+03	1.6774+03
30	1.5412+03	1.5723+03	1.5986+03	1.6185+03	1.6469+03	1.6676+03
31	1.5305+03	1.5639+03	1.5945+03	1.6135+03	1.6463+03	1.6707+03
32	1.5002+03	1.5342+03	1.5658+03	1.5858+03	1.6192+03	1.6408+03
33	1.5192+03	1.5580+03	1.5959+03	1.6190+03	1.6580+03	1.6833+03
34	1.5014+03	1.5418+03	1.5803+03	1.6047+03	1.6452+03	1.6705+03
35	1.4714+03	1.5116+03	1.5542+03	1.5800+03	1.6223+03	1.6489+03
36	1.4562+03	1.4985+03	1.5435+03	1.5696+03	1.6150+03	1.6417+03

**100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE**

	<b>398</b>	<b>406</b>	<b>414</b>	<b>430</b>	<b>438</b>	<b>446</b>
	TWO 19	TWO 20	TWO 21	TWO 23	TWO 24	TWO 25
1	1.9176+03	1.9005+03	1.8857+03	1.8901+03	1.8920+03	1.8942+03
2	1.9166+03	1.8983+03	1.8859+03	1.8912+03	1.8920+03	1.8935+03
3	1.9161+03	1.9009+03	1.8881+03	1.8999+03	1.8973+03	1.8996+03
4	1.9177+03	1.9025+03	1.8906+03	1.8984+03	1.8986+03	1.9009+03
5	1.9185+03	1.9028+03	1.8877+03	1.8973+03	1.8974+03	1.8993+03
6	1.9306+03	1.9081+03	1.8933+03	1.9016+03	1.9018+03	1.9041+03
7	1.9359+03	1.9148+03	1.8963+03	1.9051+03	1.9044+03	1.9064+03
8	1.9397+03	1.9199+03	1.8987+03	1.9062+03	1.9070+03	1.9067+03
9	1.7480+03	1.7605+03	1.7779+03	1.7495+03	1.7473+03	1.7459+03
10	1.7532+03	1.7663+03	1.7839+03	1.7533+03	1.7509+03	1.7481+03
11	1.7312+03	1.7459+03	1.7679+03	1.7489+03	1.7486+03	1.7505+03
12	1.7266+03	1.7419+03	1.7671+03	1.7502+03	1.7503+03	1.7529+03
13	1.7205+03	1.7367+03	1.7633+03	1.7538+03	1.7519+03	1.7535+03
14	1.7273+03	1.7444+03	1.7719+03	1.7546+03	1.7558+03	1.7568+03
15	1.6997+03	1.7172+03	1.7473+03	1.7575+03	1.7519+03	1.7513+03
16	1.6898+03	1.7084+03	1.7397+03	1.7587+03	1.7511+03	1.7506+03
17	1.6891+03	1.7080+03	1.7399+03	1.7724+03	1.7583+03	1.7556+03
18	1.7423+03	1.7626+03	1.7967+03	1.7587+03	1.7614+03	1.7616+03
19	1.7944+03	1.7948+03	1.7597+03	1.7644+03	1.7648+03	1.7632+03
20	1.8251+03	1.7609+03	1.7614+03	1.7657+03	1.7654+03	1.7643+03
21	1.7833+03	1.7711+03	1.7636+03	1.7670+03	1.7674+03	1.7669+03
22	1.7968+03	1.7745+03	1.7640+03	1.7690+03	1.7685+03	1.7679+03
23	1.8058+03	1.7803+03	1.7698+03	1.7749+03	1.7754+03	1.7763+03
24	1.8013+03	1.7773+03	1.7669+03	1.7706+03	1.7710+03	1.7720+03
25	1.8077+03	1.7832+03	1.7711+03	1.7754+03	1.7768+03	1.7778+03
26	1.8128+03	1.7847+03	1.7731+03	1.7769+03	1.7792+03	1.7807+03
27	1.8127+03	1.7866+03	1.7743+03	1.7784+03	1.7808+03	1.7827+03
28	1.8190+03	1.7911+03	1.7807+03	1.7831+03	1.7859+03	1.7870+03
29	1.7309+03	1.7068+03	1.6983+03	1.6994+03	1.6976+03	1.6966+03
30	1.7257+03	1.7140+03	1.7026+03	1.6982+03	1.6970+03	1.6957+03
31	1.7347+03	1.7078+03	1.7004+03	1.6993+03	1.6983+03	1.6968+03
32	1.7073+03	1.7206+03	1.7449+03	1.6996+03	1.6998+03	1.7010+03
33	1.7591+03	1.7343+03	1.7062+03	1.7053+03	1.7055+03	1.7054+03
34	1.7495+03	1.7361+03	1.7049+03	1.7037+03	1.7030+03	1.7025+03
35	1.7317+03	1.7397+03	1.7029+03	1.7075+03	1.7069+03	1.7052+03
36	1.7292+03	1.7379+03	1.7011+03	1.7071+03	1.7056+03	1.7038+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	454	462	470	478	509	516
	TWO 26	TWO 27	TB OUT	TB OUT	CND IN	CND 37
1	1.8871+03	1.8880+03	1.8401+03	1.8386+03	1.8370+03	1.8401+03
2	1.8868+03	1.8881+03	1.8390+03	1.8372+03	1.8363+03	1.8393+03
3	1.8931+03	1.8931+03	1.8430+03	1.8410+03	1.8400+03	1.8431+03
4	1.8938+03	1.8943+03	1.8432+03	1.8417+03	1.8407+03	1.8437+03
5	1.8932+03	1.8932+03	1.8412+03	1.8392+03	1.8373+03	1.8402+03
6	1.8970+03	1.8976+03	1.8436+03	1.8416+03	1.8397+03	1.8426+03
7	1.8979+03	1.8985+03	1.8444+03	1.8426+03	1.8409+03	1.8439+03
8	1.8987+03	1.8989+03	1.8437+03	1.8420+03	1.8401+03	1.8429+03
9	1.7417+03	1.7420+03	1.7208+03	1.7178+03	1.7151+03	1.7186+03
10	1.7440+03	1.7456+03	1.7220+03	1.7191+03	1.7171+03	1.7208+03
11	1.7456+03	1.7473+03	1.7192+03	1.7166+03	1.7140+03	1.7174+03
12	1.7477+03	1.7497+03	1.7208+03	1.7183+03	1.7162+03	1.7196+03
13	1.7486+03	1.7503+03	1.7219+03	1.7192+03	1.7171+03	1.7205+03
14	1.7530+03	1.7537+03	1.7190+03	1.7197+03	1.7181+03	1.7210+03
15	1.7490+03	1.7512+03	1.7177+03	1.7179+03	1.7161+03	1.7190+03
16	1.7478+03	1.7492+03	1.7164+03	1.7166+03	1.7129+03	1.7151+03
17	1.7525+03	1.7547+03	1.7168+03	1.7168+03	1.7138+03	1.7168+03
18	1.7570+03	1.7580+03	1.7191+03	1.7190+03	1.7160+03	1.7191+03
19	1.7586+03	1.7593+03	1.7208+03	1.7208+03	1.6255+03	1.7209+03
20	1.7597+03	1.7600+03	1.7199+03	1.7202+03	1.7178+03	1.7205+03
21	1.7623+03	1.7627+03	1.7206+03	1.7208+03	1.7179+03	1.7210+03
22	1.7629+03	1.7633+03	1.7207+03	1.7203+03	1.7185+03	1.7211+03
23	1.7704+03	1.7695+03	1.7245+03	1.7238+03	1.7220+03	1.7250+03
24	1.7656+03	1.7656+03	1.7207+03	1.7201+03	1.7187+03	1.7211+03
25	1.7719+03	1.7711+03	1.7239+03	1.7232+03	1.7226+03	1.7247+03
26	1.7734+03	1.7726+03	1.7247+03	1.7239+03	1.7221+03	1.7241+03
27	1.7745+03	1.7747+03	1.7248+03	1.7242+03	1.7233+03	1.7253+03
28	1.7788+03	1.7790+03	1.7280+03	1.7272+03	1.7272+03	1.7292+03
29	1.6924+03	1.6944+03	1.6688+03	1.6682+03	1.6670+03	1.6697+03
30	1.6917+03	1.6935+03	1.6682+03	1.6676+03	1.6667+03	1.6691+03
31	1.6927+03	1.6941+03	1.6677+03	1.6672+03	1.6658+03	1.6685+03
32	1.6965+03	1.6978+03	1.6688+03	1.6684+03	1.6661+03	1.6693+03
33	1.7009+03	1.7019+03	1.6712+03	1.6697+03	1.6672+03	1.6701+03
34	1.6983+03	1.6991+03	1.6698+03	1.6686+03	1.6671+03	1.6694+03
35	1.7018+03	1.7019+03	1.6706+03	1.6693+03	1.6669+03	1.6696+03
36	1.6996+03	1.6997+03	1.6683+03	1.6672+03	1.6654+03	1.6677+03

**100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE**

	<b>523</b>	<b>530</b>	<b>537</b>	<b>544</b>	<b>551</b>	<b>558</b>
	CND 38	CND 39	CND 40	CND 41	CND 42	CND 43
1	1.8192+03	1.8301+03	1.8260+03	1.8080+03	1.7074+03	1.6199+03
2	1.8172+03	1.8296+03	1.8253+03	1.8271+03	1.7496+03	1.6530+03
3	1.8202+03	1.8330+03	1.8297+03	1.8308+03	1.8343+03	1.7262+03
4	1.8197+03	1.8330+03	1.8297+03	1.8211+03	1.8382+03	1.7680+03
5	1.8164+03	1.8293+03	1.8263+03	1.8263+03	1.8353+03	1.8184+03
6	1.8183+03	1.8316+03	1.8283+03	1.8278+03	1.8368+03	1.8380+03
7	1.8185+03	1.8321+03	1.8282+03	1.8282+03	1.8375+03	1.8386+03
8	1.8177+03	1.8309+03	1.8269+03	1.8268+03	1.8361+03	1.8374+03
9	1.5965+03	1.5216+03	1.4522+03	1.4006+03	1.3510+03	1.3063+03
10	1.6052+03	1.5313+03	1.4605+03	1.4077+03	1.3571+03	1.3115+03
11	1.5940+03	1.5199+03	1.4497+03	1.3977+03	1.3478+03	1.3027+03
12	1.5976+03	1.5223+03	1.4518+03	1.4003+03	1.3505+03	1.3055+03
13	1.5988+03	1.5237+03	1.4535+03	1.4019+03	1.3521+03	1.3070+03
14	1.6100+03	1.5352+03	1.4635+03	1.4120+03	1.3619+03	1.3164+03
15	1.5919+03	1.5187+03	1.4493+03	1.3993+03	1.3504+03	1.3061+03
16	1.5849+03	1.5111+03	1.4383+03	1.3865+03	1.3347+03	1.2900+03
17	1.5937+03	1.5213+03	1.4513+03	1.4007+03	1.3520+03	1.3076+03
18	1.6524+03	1.5716+03	1.4927+03	1.4380+03	1.3850+03	1.3383+03
19	1.7054+03	1.6289+03	1.5400+03	1.4803+03	1.4231+03	1.3718+03
20	1.7061+03	1.6910+03	1.5921+03	1.5249+03	1.4642+03	1.4093+03
21	1.7069+03	1.7131+03	1.6545+03	1.5781+03	1.5100+03	1.4503+03
22	1.7077+03	1.7140+03	1.6977+03	1.6231+03	1.5472+03	1.4828+03
23	1.7076+03	1.7148+03	1.7121+03	1.7138+03	1.6818+03	1.6030+03
24	1.7059+03	1.7137+03	1.7108+03	1.7120+03	1.6890+03	1.5990+03
25	1.7071+03	1.7168+03	1.7133+03	1.7141+03	1.7202+03	1.7201+03
26	1.7078+03	1.7164+03	1.7129+03	1.7138+03	1.7203+03	1.7204+03
27	1.7083+03	1.7171+03	1.7131+03	1.7142+03	1.7207+03	1.7214+03
28	1.7111+03	1.7210+03	1.7168+03	1.7178+03	1.7246+03	1.7248+03
29	1.5933+03	1.5161+03	1.4460+03	1.3935+03	1.3433+03	1.2983+03
30	1.5942+03	1.5188+03	1.4489+03	1.3967+03	1.3469+03	1.3022+03
31	1.6063+03	1.5270+03	1.4565+03	1.4049+03	1.3576+03	1.3130+03
32	1.5914+03	1.5155+03	1.5369+03	1.3948+03	1.3453+03	1.3005+03
33	1.6505+03	1.5730+03	1.4939+03	1.4377+03	1.3831+03	1.3349+03
34	1.6455+03	1.5700+03	1.4926+03	1.4371+03	1.3833+03	1.3353+03
35	1.6357+03	1.5580+03	1.4822+03	1.4271+03	1.3746+03	1.3275+03
36	1.6392+03	1.5646+03	1.4874+03	1.4324+03	1.3798+03	1.3327+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	565	572	579	586	593	600
	CND 44	CND 45	CND 46	CND 47	CNDDIS	PUMPIN
1	1.5462+03	1.4897+03	1.4344+03	1.3879+03	1.3258+03	1.1904+03
2	1.5729+03	1.5126+03	1.4561+03	1.4074+03	1.3428+03	1.2031+03
3	1.6336+03	1.5646+03	1.4990+03	1.4460+03	1.3752+03	1.2253+03
4	1.6684+03	1.5938+03	1.5234+03	1.4678+03	1.3939+03	1.2396+03
5	1.7143+03	1.6327+03	1.5568+03	1.4962+03	1.4181+03	1.2560+03
6	1.7944+03	1.6976+03	1.6111+03	1.5411+03	1.4553+03	1.2799+03
7	1.8357+03	1.7418+03	1.6479+03	1.5727+03	1.4809+03	1.2983+03
8	1.8358+03	1.8151+03	1.7087+03	1.6222+03	1.5185+03	1.3221+03
9	1.2662+03	1.2325+03	1.1984+03	1.1698+03	1.1305+03	1.0448+03
10	1.2709+03	1.2366+03	1.2019+03	1.1728+03	1.1332+03	1.0476+03
11	1.2624+03	1.2286+03	1.1942+03	1.1652+03	1.1261+03	1.0418+03
12	1.2655+03	1.2317+03	1.1974+03	1.1686+03	1.1293+03	1.0440+03
13	1.2666+03	1.2328+03	1.1985+03	1.1696+03	1.1303+03	1.0450+03
14	1.2756+03	1.2419+03	1.2074+03	1.1779+03	1.1380+03	1.0515+03
15	1.2663+03	1.2332+03	1.1993+03	1.1706+03	1.2232+03	1.0456+03
16	1.2490+03	1.2173+03	1.1872+03	1.1600+03	1.1243+03	1.0398+03
17	1.2670+03	1.2335+03	1.1999+03	1.1711+03	1.1318+03	1.0459+03
18	1.2949+03	1.2596+03	1.2243+03	1.1933+03	1.1516+03	1.0608+03
19	1.3268+03	1.2898+03	1.2526+03	1.2198+03	1.1759+03	1.0819+03
20	1.3608+03	1.3209+03	1.2808+03	1.2462+03	1.1992+03	1.1000+03
21	1.3975+03	1.3542+03	1.3112+03	1.2749+03	1.2253+03	1.1180+03
22	1.4263+03	1.3815+03	1.3367+03	1.2984+03	1.2465+03	1.1354+03
23	1.5468+03	1.4795+03	1.4215+03	1.3766+03	1.3141+03	1.1834+03
24	1.5240+03	1.4678+03	1.4126+03	1.3670+03	1.3062+03	1.1760+03
25	1.6382+03	1.5638+03	1.4953+03	1.4403+03	1.3677+03	1.2185+03
26	1.7053+03	1.6262+03	1.5457+03	1.4820+03	1.4029+03	1.2440+03
27	1.7200+03	1.7109+03	1.6195+03	1.5436+03	1.4527+03	1.2744+03
28	1.7235+03	1.7220+03	1.6958+03	1.6029+03	1.4970+03	1.3048+03
29	1.2579+03	1.2242+03	1.1902+03	1.1612+03	1.1232+03	1.0379+03
30	1.2618+03	1.2277+03	1.1933+03	1.1647+03	1.1262+03	1.0399+03
31	1.2716+03	1.2373+03	1.2021+03	1.1727+03	1.1333+03	1.0470+03
32	1.2602+03	1.2264+03	1.1915+03	1.1629+03	1.1244+03	1.0393+03
33	1.2922+03	1.2568+03	1.2205+03	1.1895+03	1.1483+03	1.0592+03
34	1.2927+03	1.2575+03	1.2212+03	1.1905+03	1.1496+03	1.0598+03
35	1.2856+03	1.2504+03	1.2139+03	1.1833+03	1.1424+03	1.0543+03
36	1.2906+03	1.2553+03	1.2191+03	1.1882+03	1.1471+03	1.0582+03

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	607	614	621	628	635	642
	TRADTR	TRADTL	TRADM	TRADML	TRADBR	TRADBL
1	1.1295+03	1.1293+03	1.1485+03	1.1258+03	1.0480+03	1.0503+03
2	1.1394+03	1.1392+03	1.1591+03	1.1375+03	1.0578+03	1.0604+03
3	1.1598+03	1.1596+03	1.1795+03	1.1603+03	1.0783+03	1.0811+03
4	1.1701+03	1.1699+03	1.1885+03	1.1727+03	1.0891+03	1.0920+03
5	1.1778+03	1.1776+03	1.1928+03	1.1843+03	1.0997+03	1.1027+03
6	1.1922+03	1.1919+03	1.2078+03	1.2032+03	1.1169+03	1.1203+03
7	1.1980+03	1.1977+03	1.2149+03	1.2131+03	1.1273+03	1.1306+03
8	1.2053+03	1.2050+03	1.2248+03	1.2245+03	1.1395+03	1.1427+03
9	8.9023+02	8.9024+02	8.8816+02	8.8645+02	8.3481+02	8.3820+02
10	9.0021+02	9.0009+02	8.9781+02	8.9615+02	8.4316+02	8.4573+02
11	9.0638+02	9.0623+02	9.0341+02	9.0174+02	8.4515+02	8.4799+02
12	9.1666+02	9.1644+02	9.1350+02	9.1177+02	8.5265+02	8.5581+02
13	9.2635+02	9.2616+02	9.2348+02	9.2181+02	8.6080+02	8.6397+02
14	9.3578+02	9.3566+02	9.3289+02	9.3333+02	8.7241+02	8.7478+02
15	9.3780+02	9.3772+02	9.3416+02	9.3428+02	8.7248+02	8.7480+02
16	9.4439+02	9.4433+02	9.4012+02	9.4033+02	8.7682+02	8.7914+02
17	9.5206+02	9.5198+02	9.4699+02	9.4775+02	8.8278+02	8.8461+02
18	9.7351+02	9.7338+02	9.7023+02	9.7093+02	9.0384+02	9.0570+02
19	9.9272+02	9.9258+02	9.9115+02	9.9193+02	9.2287+02	9.2496+02
20	1.0123+03	1.0122+03	1.0120+03	1.0131+03	9.4224+02	9.4426+02
21	1.0313+03	1.0311+03	1.0323+03	1.0334+03	9.6018+02	9.6243+02
22	1.0454+03	1.0452+03	1.0460+03	1.0468+03	9.7279+02	9.7442+02
23	1.0874+03	1.0872+03	1.0898+03	1.0909+03	1.0133+03	1.0148+03
24	1.0822+03	1.0821+03	1.0847+03	1.0860+03	1.0088+03	1.0104+03
25	1.1105+03	1.1104+03	1.1152+03	1.1170+03	1.0392+03	1.0407+03
26	1.1210+03	1.1208+03	1.1266+03	1.1302+03	1.0515+03	1.0533+03
27	1.1334+03	1.1332+03	1.1423+03	1.1457+03	1.0677+03	1.0692+03
28	1.1422+03	1.1421+03	1.1548+03	1.1582+03	1.0812+03	1.0829+03
29	8.6512+02	8.6494+02	8.6269+02	8.6434+02	8.1649+02	8.1855+02
30	8.7781+02	8.7768+02	8.7586+02	8.7736+02	8.2658+02	8.2858+02
31	8.9243+02	8.9236+02	8.9149+02	8.9305+02	8.3942+02	8.4157+02
32	8.9531+02	8.9523+02	8.9367+02	8.9512+02	8.3946+02	8.4180+02
33	9.3041+02	9.3028+02	9.2852+02	9.3073+02	8.6971+02	8.7227+02
34	9.3708+02	9.3701+02	9.3541+02	9.3758+02	8.7531+02	8.7783+02
35	9.4139+02	9.4134+02	9.3991+02	9.4219+02	8.7793+02	8.8057+02
36	9.5187+02	9.5182+02	9.4992+02	9.5238+02	8.8546+02	8.8818+02

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	663	799	819	823	839	842
	PHCASE	QN PH	QN B	Q/A	FLOW	G
1	8.7599+02	9.5120-01	1.7797+01	1.2505+05	6.9973-02	8.3890+04
2	8.7988+02	9.6240-01	1.8447+01	1.2962+05	7.0097-02	8.4038+04
3	8.8765+02	9.5120-01	1.9403+01	1.3634+05	7.0342-02	8.4331+04
4	8.9109+02	9.6585-01	2.0073+01	1.4105+05	7.0084-02	8.4023+04
5	8.9564+02	9.6585-01	2.0895+01	1.4682+05	7.0841-02	8.4931+04
6	9.0097+02	9.4100-01	2.1747+01	1.5280+05	7.0892-02	8.4991+04
7	9.0569+02	9.3520-01	2.2517+01	1.5822+05	7.0892-02	8.4992+04
8	9.1107+02	9.6240-01	2.3259+01	1.6343+05	7.0924-02	8.5029+04
9	1.1157+03	4.8857+00	6.8379+00	4.8047+04	6.9657-02	8.3510+04
10	1.0896+03	4.4390+00	7.3247+00	5.1468+04	6.9247-02	8.3019+04
11	1.0521+03	3.8750+00	7.6703+00	5.3896+04	6.9516-02	8.3342+04
12	1.0224+03	3.4380+00	8.0934+00	5.6869+04	6.9494-02	8.3316+04
13	9.8659+02	2.9560+00	8.6811+00	6.0999+04	6.9481-02	8.3300+04
14	9.5134+02	2.4725+00	9.1550+00	6.4328+04	6.9535-02	8.3364+04
15	9.0055+02	1.9350+00	9.3478+00	6.5683+04	6.9817-02	8.3703+04
16	8.5037+02	1.4630+00	9.7526+00	6.8528+04	6.9789-02	8.3669+04
17	7.8576+02	9.5205-01	1.0318+01	7.2497+04	6.9729-02	8.3597+04
18	7.9139+02	9.5205-01	1.0888+01	7.6506+04	6.9555-02	8.3388+04
19	7.9929+02	9.6300-01	1.1640+01	8.1788+04	6.9750-02	8.3622+04
20	8.0601+02	9.4860-01	1.2523+01	8.7996+04	6.9937-02	8.3846+04
21	8.1243+02	9.3760-01	1.3403+01	9.4176+04	7.0497-02	8.4517+04
22	8.1635+02	9.5550-01	1.4083+01	9.8956+04	7.0618-02	8.4662+04
23	8.3336+02	9.5550-01	1.6086+01	1.1303+05	7.0042-02	8.3972+04
24	8.3065+02	9.4970-01	1.5758+01	1.1073+05	7.0015-02	8.3940+04
25	8.4463+02	9.3760-01	1.7339+01	1.2183+05	7.0048-02	8.3979+04
26	8.5013+02	9.3080-01	1.8151+01	1.2754+05	6.9895-02	8.3795+04
27	8.6137+02	9.7000-01	1.9000+01	1.3351+05	6.9827-02	8.3714+04
28	8.6893+02	9.5550-01	1.9775+01	1.3895+05	7.0055-02	8.3988+04
29	1.1066+03	4.9099+00	6.4959+00	4.5644+04	6.9520-02	8.3346+04
30	1.0762+03	4.4272+00	6.9305+00	4.8698+04	6.9516-02	8.3342+04
31	1.0461+03	3.8750+00	7.4615+00	5.2429+04	6.9539-02	8.3369+04
32	1.0144+03	3.4057+00	7.7433+00	5.4409+04	6.9473-02	8.3289+04
33	9.8401+02	2.9200+00	9.0216+00	6.3391+04	6.9621-02	8.3467+04
34	9.4934+02	2.5149+00	9.3613+00	6.5778+04	6.9630-02	8.3478+04
35	9.0132+02	1.9570+00	9.7567+00	6.8557+04	6.9193-02	8.2955+04
36	8.4879+02	1.4737+00	1.0148+01	7.1306+04	6.9525-02	8.3352+04

100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	853	855	858	859	1003	1010
	X OUT	EB OUT	VELOUT	P SAT	TWI 8	TWI 9
1	1.7592-01	5.7282+02	2.2539+01	9.2039+01	1.3349+03	1.3858+03
2	1.9052-01	5.8332+02	2.4541+01	9.1668+01	1.3471+03	1.3985+03
3	2.1208-01	5.9974+02	2.7045+01	9.2887+01	1.3726+03	1.4286+03
4	2.2830-01	6.1168+02	2.8954+01	9.3034+01	1.3834+03	1.4410+03
5	2.4663-01	6.2478+02	3.1900+01	9.2310+01	1.4115+03	1.4677+03
6	2.6612-01	6.3939+02	3.4118+01	9.3084+01	1.4301+03	1.4907+03
7	2.8490-01	6.5326+02	3.6398+01	9.3372+01	1.4480+03	1.5118+03
8	3.0486-01	6.6779+02	3.9061+01	9.3172+01	1.4740+03	1.5415+03
9	3.2696-02	4.4255+02	6.3397+00	5.9759+01	1.4133+03	1.4340+03
10	3.5619-02	4.4506+02	6.8365+00	6.0048+01	1.3907+03	1.4118+03
11	3.1724-02	4.4153+02	6.1669+00	5.9462+01	1.3507+03	1.3723+03
12	3.2254-02	4.4227+02	6.2340+00	5.9817+01	1.3243+03	1.3478+03
13	3.6471-02	4.4572+02	7.0229+00	6.0057+01	1.2945+03	1.3191+03
14	3.9011-02	4.4742+02	7.5490+00	5.9778+01	1.2755+03	1.3025+03
15	3.2645-02	4.4221+02	6.3760+00	5.9436+01	1.2366+03	1.2641+03
16	3.3659-02	4.4272+02	6.6006+00	5.9145+01	1.2093+03	1.2379+03
17	3.7333-02	4.4560+02	7.3071+00	5.9213+01	1.1829+03	1.2127+03
18	5.0715-02	4.5633+02	9.8269+00	5.9708+01	1.1994+03	1.2305+03
19	6.8153-02	4.7006+02	1.3165+01	6.0108+01	1.2211+03	1.2548+03
20	8.7702-02	4.8491+02	1.7028+01	5.9935+01	1.2400+03	1.2769+03
21	1.0618-01	4.9921+02	2.0736+01	6.0090+01	1.2616+03	1.3016+03
22	1.2158-01	5.1098+02	2.3802+01	6.0033+01	1.2794+03	1.3187+03
23	1.7002-01	5.4876+02	3.2616+01	6.0888+01	1.3301+03	1.3764+03
24	1.6398-01	5.4348+02	3.1840+01	6.0011+01	1.3259+03	1.3708+03
25	2.0108-01	5.7246+02	3.8651+01	6.0754+01	1.3709+03	1.4188+03
26	2.2179-01	5.8844+02	4.2433+01	6.0927+01	1.3950+03	1.4463+03
27	2.4530-01	6.0649+02	4.6854+01	6.0975+01	1.4243+03	1.4796+03
28	2.6420-01	6.2142+02	5.0119+01	6.1695+01	1.4522+03	1.5106+03
29	4.5513-02	4.4211+02	1.0616+01	4.9115+01	1.4138+03	1.4332+03
30	4.0600-02	4.3815+02	9.4938+00	4.8994+01	1.3831+03	1.4041+03
31	4.3073-02	4.3999+02	1.0093+01	4.8910+01	1.3567+03	1.3791+03
32	3.8850-02	4.3693+02	9.0527+00	4.9133+01	1.3204+03	1.3433+03
33	5.8063-02	4.5228+02	1.3460+01	4.9487+01	1.3128+03	1.3395+03
34	5.8164-02	4.5212+02	1.3550+01	4.9253+01	1.2878+03	1.3156+03
35	5.5201-02	4.4995+02	1.2741+01	4.9397+01	1.2447+03	1.2758+03
36	5.5584-02	4.4981+02	1.3007+01	4.8966+01	1.2181+03	1.2513+03

**100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE**

	<b>1017</b>	<b>1024</b>	<b>1031</b>	<b>1038</b>	<b>1045</b>	<b>1052</b>
	<b>TWI 10</b>	<b>TWI 11</b>	<b>TWI 12</b>	<b>TWI 13</b>	<b>TWI 14</b>	<b>TWI 15</b>
1	1.5617+03	1.6460+03	1.7055+03	1.7836+03	1.8509+03	1.8907+03
2	1.5832+03	1.6682+03	1.7300+03	1.8054+03	1.8748+03	1.8691+03
3	1.6231+03	1.7149+03	1.7761+03	1.8521+03	1.8753+03	1.8402+03
4	1.6430+03	1.7353+03	1.7980+03	1.8708+03	1.8518+03	1.8499+03
5	1.6747+03	1.7639+03	1.8260+03	1.8919+03	1.8584+03	1.8456+03
6	1.7066+03	1.7973+03	1.8585+03	1.8813+03	1.8592+03	1.8469+03
7	1.7345+03	1.8230+03	1.8786+03	1.8621+03	1.8586+03	1.8460+03
8	1.7685+03	1.8595+03	1.9099+03	1.8594+03	1.8569+03	1.8465+03
9	1.5102+03	1.5375+03	1.5557+03	1.5852+03	1.6114+03	1.6300+03
10	1.4932+03	1.5234+03	1.5428+03	1.5753+03	1.6043+03	1.6241+03
11	1.4592+03	1.4896+03	1.5111+03	1.5438+03	1.5756+03	1.5958+03
12	1.4393+03	1.4730+03	1.4953+03	1.5284+03	1.5635+03	1.5837+03
13	1.4158+03	1.4513+03	1.4764+03	1.5104+03	1.5482+03	1.5689+03
14	1.4021+03	1.4426+03	1.4660+03	1.5042+03	1.5439+03	1.5662+03
15	1.3636+03	1.4071+03	1.4321+03	1.4709+03	1.5128+03	1.5350+03
16	1.3424+03	1.3850+03	1.4118+03	1.4525+03	1.4957+03	1.5191+03
17	1.3254+03	1.3687+03	1.3960+03	1.4388+03	1.4838+03	1.5088+03
18	1.3502+03	1.3987+03	1.4282+03	1.4737+03	1.5229+03	1.5497+03
19	1.3811+03	1.4327+03	1.4638+03	1.5120+03	1.5625+03	1.5925+03
20	1.4102+03	1.4647+03	1.4959+03	1.5477+03	1.6023+03	1.6320+03
21	1.4424+03	1.4979+03	1.5336+03	1.5889+03	1.6459+03	1.6780+03
22	1.4653+03	1.5234+03	1.5597+03	1.6156+03	1.6730+03	1.7080+03
23	1.5424+03	1.6112+03	1.6519+03	1.7146+03	1.7775+03	1.7996+03
24	1.5354+03	1.6030+03	1.6434+03	1.7052+03	1.7678+03	1.7903+03
25	1.5990+03	1.6713+03	1.7123+03	1.7755+03	1.7490+03	1.7318+03
26	1.6315+03	1.7082+03	1.7498+03	1.7499+03	1.7339+03	1.7280+03
27	1.6734+03	1.7505+03	1.7895+03	1.7335+03	1.7379+03	1.7293+03
28	1.7090+03	1.7847+03	1.7641+03	1.7377+03	1.7393+03	1.7284+03
29	1.5024+03	1.5287+03	1.5453+03	1.5748+03	1.5979+03	1.6157+03
30	1.4788+03	1.5062+03	1.5254+03	1.5565+03	1.5828+03	1.6028+03
31	1.4616+03	1.4925+03	1.5134+03	1.5468+03	1.5775+03	1.5965+03
32	1.4301+03	1.4603+03	1.4824+03	1.5165+03	1.5481+03	1.5681+03
33	1.4370+03	1.4728+03	1.4985+03	1.5374+03	1.5753+03	1.5985+03
34	1.4172+03	1.4545+03	1.4800+03	1.5204+03	1.5590+03	1.5834+03
35	1.3811+03	1.4214+03	1.4490+03	1.4892+03	1.5320+03	1.5577+03
36	1.3621+03	1.4038+03	1.4329+03	1.4753+03	1.5203+03	1.5464+03

**100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE**

	<b>1059</b>	<b>1066</b>	<b>1080</b>	<b>1087</b>	<b>1094</b>	<b>1108</b>
	<b>TWI 16</b>	<b>TWI 17</b>	<b>TWI 19</b>	<b>TWI 20</b>	<b>TWI 21</b>	<b>TWI 23</b>
1	1.8581+03	1.8624+03	1.8779+03	1.8608+03	1.8459+03	1.8503+03
2	1.8480+03	1.8626+03	1.8755+03	1.8571+03	1.8447+03	1.8500+03
3	1.8478+03	1.8645+03	1.8728+03	1.8576+03	1.8448+03	1.8565+03
4	1.8498+03	1.8604+03	1.8729+03	1.8577+03	1.8458+03	1.8536+03
5	1.8446+03	1.8540+03	1.8719+03	1.8562+03	1.8410+03	1.8506+03
6	1.8481+03	1.8556+03	1.8821+03	1.8596+03	1.8447+03	1.8530+03
7	1.8467+03	1.8592+03	1.8858+03	1.8646+03	1.8460+03	1.8549+03
8	1.8495+03	1.8650+03	1.8879+03	1.8681+03	1.8468+03	1.8543+03
9	1.6590+03	1.6780+03	1.7326+03	1.7451+03	1.7625+03	1.7340+03
10	1.6547+03	1.6767+03	1.7367+03	1.7498+03	1.7674+03	1.7368+03
11	1.6278+03	1.6501+03	1.7139+03	1.7286+03	1.7507+03	1.7317+03
12	1.6179+03	1.6404+03	1.7084+03	1.7237+03	1.7489+03	1.7319+03
13	1.6047+03	1.6288+03	1.7009+03	1.7171+03	1.7437+03	1.7343+03
14	1.6055+03	1.6318+03	1.7066+03	1.7238+03	1.7513+03	1.7339+03
15	1.5747+03	1.6015+03	1.6785+03	1.6961+03	1.7262+03	1.7365+03
16	1.5609+03	1.5864+03	1.6677+03	1.6864+03	1.7177+03	1.7367+03
17	1.5530+03	1.5798+03	1.6658+03	1.6847+03	1.7166+03	1.7492+03
18	1.5974+03	1.6262+03	1.7177+03	1.7380+03	1.7722+03	1.7342+03
19	1.6419+03	1.6722+03	1.7683+03	1.7686+03	1.7335+03	1.7382+03
20	1.6848+03	1.7160+03	1.7970+03	1.7327+03	1.7332+03	1.7375+03
21	1.7323+03	1.7651+03	1.7532+03	1.7409+03	1.7334+03	1.7368+03
22	1.7632+03	1.7969+03	1.7652+03	1.7428+03	1.7323+03	1.7373+03
23	1.7361+03	1.7464+03	1.7696+03	1.7441+03	1.7336+03	1.7387+03
24	1.7333+03	1.7407+03	1.7659+03	1.7418+03	1.7314+03	1.7351+03
25	1.7303+03	1.7407+03	1.7687+03	1.7442+03	1.7321+03	1.7364+03
26	1.7321+03	1.7454+03	1.7720+03	1.7439+03	1.7322+03	1.7361+03
27	1.7296+03	1.7434+03	1.7700+03	1.7438+03	1.7316+03	1.7357+03
28	1.7323+03	1.7498+03	1.7746+03	1.7466+03	1.7363+03	1.7386+03
29	1.6426+03	1.6627+03	1.7162+03	1.6921+03	1.6836+03	1.6847+03
30	1.6312+03	1.6519+03	1.7100+03	1.6984+03	1.6869+03	1.6825+03
31	1.6294+03	1.6538+03	1.7178+03	1.6909+03	1.6835+03	1.6824+03
32	1.6016+03	1.6232+03	1.6898+03	1.7031+03	1.7274+03	1.6821+03
33	1.6375+03	1.6629+03	1.7388+03	1.7139+03	1.6858+03	1.6849+03
34	1.6240+03	1.6493+03	1.7284+03	1.7149+03	1.6837+03	1.6826+03
35	1.6001+03	1.6268+03	1.7096+03	1.7177+03	1.6808+03	1.6855+03
36	1.5919+03	1.6187+03	1.7063+03	1.7150+03	1.6781+03	1.6841+03

## 100 KW BOILING POTASSIUM DATA FOR 0.742 I.D. TUBE

	1115	1122	1129	1136	1137	1138
	TWI 24	TWI 25	TWI 26	TWI 27	DT 27	H 27
1	1.8523+03	1.8545+03	1.8473+03	1.8482+03	8.8591+00	1.4116+04
2	1.8508+03	1.8523+03	1.8456+03	1.8469+03	8.7521+00	1.4810+04
3	1.8540+03	1.8563+03	1.8498+03	1.8498+03	7.7634+00	1.7562+04
4	1.8537+03	1.8561+03	1.8490+03	1.8495+03	7.0361+00	2.0046+04
5	1.8508+03	1.8527+03	1.8465+03	1.8466+03	6.3752+00	2.3030+04
6	1.8532+03	1.8556+03	1.8485+03	1.8490+03	6.4225+00	2.3792+04
7	1.8542+03	1.8561+03	1.8477+03	1.8483+03	4.7865+00	3.3055+04
8	1.8551+03	1.8548+03	1.8468+03	1.8470+03	4.1201+00	3.9668+04
9	1.7319+03	1.7305+03	1.7262+03	1.7266+03	7.2946+00	6.5867+03
10	1.7344+03	1.7316+03	1.7275+03	1.7291+03	8.5234+00	6.0384+03
11	1.7313+03	1.7332+03	1.7283+03	1.7300+03	1.2067+01	4.4665+03
12	1.7321+03	1.7346+03	1.7295+03	1.7315+03	1.1920+01	4.7708+03
13	1.7323+03	1.7340+03	1.7291+03	1.7307+03	1.0138+01	6.0171+03
14	1.7351+03	1.7362+03	1.7324+03	1.7330+03	1.3666+01	4.7072+03
15	1.7308+03	1.7302+03	1.7279+03	1.7301+03	1.2338+01	5.3235+03
16	1.7291+03	1.7286+03	1.7258+03	1.7272+03	1.0765+01	6.3658+03
17	1.7351+03	1.7324+03	1.7293+03	1.7314+03	1.4655+01	4.9469+03
18	1.7368+03	1.7370+03	1.7325+03	1.7335+03	1.4449+01	5.2950+03
19	1.7386+03	1.7370+03	1.7324+03	1.7331+03	1.2279+01	6.6610+03
20	1.7372+03	1.7360+03	1.7314+03	1.7318+03	1.1736+01	7.4983+03
21	1.7373+03	1.7367+03	1.7321+03	1.7325+03	1.1815+01	7.9707+03
22	1.7368+03	1.7362+03	1.7312+03	1.7315+03	1.1045+01	8.9595+03
23	1.7392+03	1.7401+03	1.7342+03	1.7333+03	9.1811+00	1.2311+04
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29	1.6829+03	1.6819+03	1.6777+03	1.6797+03	1.1165+01	4.0882+03
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